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THE CHARACTERIZATION AND UTILIZATION OF BARK AS A FLORICULTURE GROWING MEDIUM

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THE CHARACTERIZATION AND UTILIZATION OF BARK
AS A FLORICULTURE GROWING MEDIUM

by

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DISSERTATION

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This dissertation has been examined and approved.

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ABSTRACT

THE CHARACTERIZATION AND UTILIZATION OF

BARK AS A FLORICULTURE GROWING MEDIUM

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The use of fresh, inprocessed bark as a component of a soil-less medium for selected pot grown floriculture crops was evaluated.

Blends of bark of northern hardwood and softwood tree species from two New Hampshire sources were physically and chemically characterized. Measurements included N, P, K, Ca, Mg, pH, and total soluble salts on growing media and spectrographic analyses of plant leaves.

Observations, including height and fresh weight, of the chrysanthemum cultivar "Bright Golden Anne" (Chrysanthemum morifolium Ramat) in media containing various amounts of the two bark blends in combination with vermiculite and perlite were evaluated. Treatments consisting of various formulations and rates of the slow-release fertilizers Magamp and Osmocote were applied in three separate experiments. In a fourth experiment, four different rates of NH_4NO_3 were compared with a 20-20-20 fertilizer application.

The data indicated that Osmocote produced taller, heavier, and generally better quality plants than Magamp with most hardwood bark mixtures but not significantly better plants in softwood mixtures. This was attributed to the higher NO_3 content of Osmocote and the more rapid rate of decomposition and subsequent demands for soil nitrogen in hardwood bark mixes. The higher rates of any of the fertilizer treatments produced the best plants. Raw bark media must be fertilized with sufficient nitrogen at a rate of at least 400 ppm per week applied in enough quantity to thoroughly saturate the volume of the container used.

While raw screened bark can be utilized as a growing medium, best results were usually obtained when bark constituted between 50 percent and 75 percent of the total mixture by volume. Coarse particles in both the fresh hardwood and softwood mixtures created greater aeration and drainage than comparable products. Vermiculite was the best overall inorganic component throughout the experiments.

When properly watered and fertilized, mixtures of hardwood and softwood bark can be effectively used as the organic component in an artificial growing medium for container-grown florist crops.

INTRODUCTION

Woodlands now comprise about eighty-six percent of the total land area in the state of New Hampshire. Trees are a renewable natural resource with a great potential for continued economic impact upon the area. The forest industry is, however, concerned with the problem of disposing of its waste by-products. In New Hampshire, sawmills produce about 180,000 tons of bark annually. Alternative uses for bark residue are needed that will eliminate dangers of environmental pollution. Increased fuel costs and other economic considerations have prompted some bark producers to modify procedures to enable burning or more complete utilization of some of their wood residue. The increased demand for decorative bark mulch reduced the disposal problem for small mill operators. However, a use of the bark more profitable than mulch would have a beneficial impact upon the forest industry.

In New England an expanding horticulture industry is in need of a constant supply of growing media. Sufficient quantities of uniform native soil are frequently unavilable or unsuitable for producing ornamental plants without extensive and expensive amending or handling. Replenishment of soil is a special problem in the North-east for those involved with floriculture crops. Greenhouse production techniques have changed in recent years with the majority of the plants now being grown in pots or containers of some sort. Thus, the need exists for a constant replenishment of a medium that will produce quality plants under highly specialized growing conditions.

In an effort to increase efficiency and meet competition from other production areas, many local growers of short-term potted plants have used artificial or soilless mixes. A uniform standard growing medium makes greater utilization of mechanization or automation possible and thereby lowers production costs. Artificial soil mixes have been developed that are adapted to new material handling methods and cultural techniques. These mixes provide a plant growing medium free from weed seeds, insects, and plant pathogens. They are relatively light in weight, hold adequate nutrients and moisture, provide sufficient drainage to insure aeration, and are economically feasible. The most widely used artificial mixes in current use utilize imported sphagnum peatmoss as the major component. However, in recent years, the cost of this material has risen sharply. There have also been problems with the supply, quality control, and transportation of imported peat products and commercial peat mixes.

In several sections of the United States, local tree bark has been utilized as a component of artificial mixes or soil mixes to grow a range of woody plants or florist crops. Preliminary research conducted at the University of New Hampshire's Plant Science Department indicated the potential value of blends of Northeast tree bark as the organic constituent in an artificial medium for specialized short-term floriculture plant production. Special emphasis was placed on the needs of the small greenhouse business typical of the Northeast and the possible direct utilization of bark products which receive no special treatment and processing by the bark supplier or producer.

The objectives of this research were as follows:

1. To evaluate hardwood and softwood bark available from New Hampshire sources as a media component for floriculture crops.

2. To characterize available blends of both hardwood and softwood barks in terms of physical and chemical properties.

3. To develop an artificial soil media with appropriate nutrient amendments which would have possible commercial application.

4. To analyze chrysanthemum plants grown in bark media with consideration for critical nutrient content.

Four experiments were conducted to meet these objectives. The first provided a broad evaluation of different bark mixtures in conjunction with an artificial peat-vermiculite mix and a standard greehouse soil mixture. The second experiment expanded observations on additional bark combinations and their physical properties. Plant response to four slow-release fertilizer formulations were also noted. The third experiment focused upon the apparent limitations that deficiencies of nitrogen impose upon plant growth which were noted in the first two trials. Plant response to increased rates of a slow-release fertilizer were compared. The primary objective of the fourth experiment was to determine the effects that different rates of NH_4NO_3 would have upon chrysanthemum growth compared to a 20-20-20 fertilizer.

REVIEW OF LITERATURE

General Wood Product Residue Utilization

One of the problems facing the forest products industry is the need to find economical uses for bark and other wood residues. At the time of initiation of experiments in New Hampshire, the Groveton Paper Company was generating 50,000 cubic meters of bark per year. The accumulation of large volumes of waste by-products generated by wood-based product manufacturers was documented by Mater (1967). Surplus bark is one of the forest industry's greatest disposal concerns. Hartkin and Rowe (1969) reported that bark comprises from 9 to 15 percent of a typical log by volume and slightly more on a dry-weight basis. They found that there are roughly 101 kilograms of bark per cord of wood. Thomas and Behr (1970) conducted a survey and made observations on the nature and quantity of wood residues at mills and identified potential uses and market demands for these products in almost every community in Michigan. The search for new uses, rather than dumping or burning, was recognized even before the enactment of strict laws pertaining to air and water pollution control (Field, 1958).

According to Allison (1970a), most producers of bark by-products have recognized that this material does have a value if properly processed for specific end-products and if channeled into appropriate market outlets. However, many producers are reluctant to develop secondary disposal enterprises or invest up to $600,000 for complete processing and bagging operations. Several forestry industry authorities have noted the importance of business management and marketing skills in the development and utilization of bark products (Ivory and Field, 1959; Kelly, 1970; Lamb, 1970; Love, 1970; Oettinger, 1970; and Hartzell, 1970). Mill operators themselves must analyze local supplies and markets, then make the commitment for manufacturing, maintaining quality control, promoting, and delivering their product.

Physical and Chemical Properties of Bark and Wood Residues

There are many variables influencing the components and structure of wood residue. The tree species, site, condition of the tree, time of year and debarking method all have an impact on bark quality. The rosser-head machine commonly used in smaller mills will remove bark in small particles. However, up to 50 percent of the total residue may be wood depending upon the tree species and the conformity of the log. Ring and drum debarkers will include 10 percent or less wood in their bark residue. Bark comes off most tree species in larger pieces and is removed easiest during spring and summer regardless of the method used. Barks range in thickness from 30 cm or more for west coast species to less than 1.25 cm in beech, paper birch, and soft maple. Some barks contain more resins and gums than others. Some can be removed in large chunks while other species are very fibrous. (Allison, 1970a)

Much of the research on bark or wood particulate properties and chemical extracts has been conducted by forest industry investigators seeking to expand knowledge on specific gravity, particle size and strength, moisture content, absorption rates, pH, heat of combustion and chemical derivatives (Mater, 1967; Martin and Christ, 1968; Harkin and Rowe, 1969; Murphey, Beall, Cutter and Baldwin, 1970; Aaron, 1973; and Isomaki, 1974). Their concern was primarily for the potential utilization of material for such things as building boards, filters, chemical extenders, trickle filter media, charcoal, compressed fireplace logs, oil pollution control, and chemical extracts. However, the implications of some of this work also relate to possible agricultural utilization. Allison (1970b) groups the end-product uses of bark into either high volume-low value uses or low volume-high value uses according to their physical, thermal, mechanical or chemical properties.

Cation exchange capacity for barks ranging from 6.5 to 44 m.e./100 grams were reported by Bollen (1969) and Scott and Bearce (1972). Carbon to nitrogen ratios were also reported by researchers working on the decomposition of barks and the use of barks as a growing medium (Allison and Klein, 1961; Allison and Murphy, 1962; and Bollen, 1969). C/N ratios ranged lower for most hardwood species (Yellow Poplar 136:1, White Oak 300:1) and higher for softwoods (White Pine 510:1). Most blends of hardwood species have a C/N ratio of between 200 and 350 to 1. Additional information on northeast tree species was reported by Young (1971) who determined the relative amount of bark present in eight species of trees and the percent of twelve elements contained in their respective barks. Nitrogen content averaged .34 percent for the barks tested.

The properties of bark and their possible impact were summarized by Mater (1968) as follows:

Physical Properties:	Influences:
Color	Heating by sun, consumer appeal
Particle size	Absorptive capacity for water, gases, nutrients
Structure	Texture, porosity, aeration, feel
Specific gravity	Weight
Water content	Wettability
Chemical Properties:	**Influences:**
Carbohydrates, fats, protein	Susceptibility to microbial action
Ligno-celluloses	Rate of decomposition
Phenolics, extractives	Acidity, toxicity
C.E.C.	Buffer capacity
Nutrient elements	Fertilizing value

The possibility of toxic compounds in bark that might injure plants has largely been dispelled. However, bark leachates from freshly harvested Silver Maple and Black Walnut that was used within five days reduced plant growth (Haramaki, Nuss, and Oliver, 1970; and Gartner, Still, and Klett, 1973). Low pH, tannins, and high trace element content were suggested as possible causes. Fewer problems were noted with bark harvested in spring or summer, and no problems were observed if the bark had been held for 30 days or composted. Bollen and Lu (1966) reported that harmful volatile organic acids accumulate in the absence of free oxygen and excessive heat. This situation can occur if fresh moist bark or sawdust is piled too deep and is compacted, allowing anerobic fermentation to take place.

Horticultural Uses of Wood Residue

Researchers and authorities in the field of forest product utilization generally believe that agricultural usage of wood processing by-products is feasible and promising. In the northeast most agricultural enterprises are located within thirty miles of some wood residue producer. Wood chips, sawdust, and bark have been used successfully as mulches, soil stabilizers, animal and poultry litter, propagation media, nursery-stock packing material and as a field soil amendment for crops (Allison and Anderson, 1951; McIntyre, 1952; Dunn, 1956; Burton, 1959; Bollen and Glennie, 1961a,b; Porkorny and Perkins, 1967; Mater, 1968; Haramaki, Nuss, and Williams, 1969; Wright and Fitzgerald, 1969, 1972; Cowen, 1973; and Yocum, 1975).

Growing plants in bark and wood residue after it has been combined or composed with cattle or poultry manure or with sewage sludge has been demonstrated successfully by Shanks (1976); Gouin (1978); Chaney, Munns, and Cathey (1980); and Wootten, Gouin, and Stark (1981).

General Container Production

More than ever, ornamental horticultural crops are now being grown in containers of various kinds. The quality of the medium used for growing plants in containers will often determine the degree of success in producing the crop. A satisfactory medium for ornamental plants should be porous and well drained and still retain sufficient moisture for plant development. In general, a container medium should consist of 50 percent solid particles and 50 percent pore space. Following watering and gravitational drainage, 50 percent of the pores should be filled with water and 50 percent with air (Manaker, 1981). A container medium should be relatively low in soluble salts, adequate in exchange capacity to retain and supply elements for plant growth, uniform to permit standardized fertilization and irrigation, free from harmful pests and pathogens, and biologically and chemically stable (Mastalerz, 1977). McGuire (1972) pointed out that in contrast to general field production, the volume of a medium available per plant is greatly reduced and must have specific characteristics for optimum plant growth. It must retain sufficient moisture between irrigations and be porous enough for adequate gas exchange. The medium should not shrink away from the side of the container or become compacted and should provide optimum conditions for specific plants in terms of organic matter content and pH.

A medium in a container is distinguished from the same material in ground bed by its smaller volume and shallower depth. Lack of volume limits total water and mineral storage. Shallowness causes excess medium water retention and poor aeration because of a perched water table formed at the container bottom after irrigation. Moisture dynamics in container mixes can be altered by amendment particle size, shape, and distribution (White and Mastalerz, 1966; Spoomer, 1974; and Paul and Lee, 1976).

Many studies have been conducted with lightweight components and media which are readily available in different areas. Five different peat and sand mixtures for containers were developed and reported by Baker (1957). These basic soilless U.C. mixtures ranged from 100 percent fine sand to 100 percent peat moss and have become widely known and accepted by growers. The Cornell peat-lite mixes were developed as a substitute for scarce and variable topsoil. They consist of blends of peat moss with vermiculite or perlite (Boodley and Sheldrake, 1972). These mixes have found application for a wide range of container grown plants and have served as the basic formulation for several commercial products. Boodley (1981) states that soilless media should have these advantages: known properties, be derived from components which are easy to obtain, mix, and use; low nutrient content so fertilizers can be added in known amounts; some readily available K and Mg; and sterile materials that do not require additional treatment prior to greenhouse use.

Bark as a Container Medium

The use of raw bark alone as a container medium has been limited primarily to epiphytic orchids. Fir barks have been successfully used; however, infestations of insects and arthropods and loss of structure upon eventual decomposition were observed as problems (Davidson, 1961; and Lunt and Kofranek, 1961).

In areas where the supply of peat is exhausted or is becoming more expensive, bark and other wood residues have been investigated as an amendment in various container mixes for nursery and florist crops (Lunt and Clark, 1959; Joiner and Conover, 1967; Gartner, Meyer, Saupe, 1971; Still, Gartner and Hughes, 1972; Lumis, 1974; and Albery, 1975).

The practical use of bark as the major component of container mixes has been demonstrated by several researchers including Rigby (1963), Bosley (1967), Scott and Bearce (1970), and Gartner, Hughes, and Klett (1972). However, the use of bark as a growing medium has produced variability in results experienced by both researchers and growers. This variability is due in part to differences in the degree of mechanical processing or composting before utilization of the product. Isomaki (1974) noted that pH, moisture equivalents, and cation exchange capacities changed with composting.

A major factor in causing differences in container plant growth was the variation in particle size of the bark which affects the bulk density and porosity of the media. Gartner, Still, and Klett (1973) used bark that was hammermilled at the mill to pass through a 1.87-cm screen then grew plants in various mixtures containing specific particles obtained from each of six progressively smaller mesh screenings. Plants grown in particles sized less than .8 mm had poor growth due to inadequate aeration. Those grown in particles about 6.4 mm in size also did poorly because of rapid drying and low moisture. When particle sizes were combined, the best growth resulted when between 20 and 40 percent of the particles were below .8 mm and 10 to 20 percent were above 6.4 mm. Similar ranges were proposed by Porkorny and Perkins (1967) and Gartner, Still, and Klett (1975). Generally, bark is hammermilled and screened so all particles pass through a 1.25-cm screen. However, composting is another means of reducing particle size and bringing the carbon-nitrogen ratio of barks down to a manageable range of between 50 and 25 to 1 for use in container media. The addition of nitrogen (N) prior to composting is also beneficial. Composting hardwood bark also suppresses all soil-borne pathogens that have been examined (Still, Dirr, and Gartner, 1974; Hoitnik, Schmitthennier, and Herr, 1975; and Hoitnik and Poole, 1979). Spomer (1974, 1975) conducted studies to develop a method to predict the porosity of any hardwood bark-soil mixture as an index for determining the optimum amount of hardwood bark amendment. He was also able to determine that 75 percent of the water absorbed by bark is unavailable to plants. Saturated bark contains about 40 percent water.

Plant nutrition and pH was a major consideration in much of the work done on bark used in container plant production. Gartner (1978) reported that hardwood bark increases in pH as it ages. His particular blend of freshly harvested bark had a pH of 5.2 initially which increased to a range of 7.5 to 8.0 by the end of the experiment. The increase was attributed to a 4 percent calcium content in the bark. Pine bark usually has a lower pH, often similar to peat moss, and plants grown in such materials may benefit from incorporation of ground limestone (Lunt and Clark, 1959).

Nitrogen deficiency in bark media is mentioned by most researchers. When bark is incorporated in a medium, higher plants that are competing with micro-organisms for available N may suffer from a deficiency. To alleviate the problem, Bosley (1967) suggested that bark be exposed to anhydrous ammonia in a closed auger system or add a material such as bloodmeal. Bollen and Glennie (1963) found that fir bark could be treated with nitric acid, urea, or ammonia hydroxide to prevent N starvation in most crops.

Scott and Bearce (1972) grew chrysanthemums in hardwood bark fines and sawdust by using combinations of $CaNO_3$, NH_4NO_3, Magamp, and Hoagland's solution. Bark-vermiculite and bark-sawdust produced poor quality plants due to low N levels. Nitrogen fertilizer studies on hardwood bark were conducted by Gartner, Still, and Klett (1975). In the first experiment, N deficiencies could not be overcome with a 12-12-12 fertilizer without running into soluble salt problems. In another trial, the slow-release fertilizers, urea formaldahyde, Magamp, and Osmocote were compared and Osmocote 18-6-12 gave the best growth of chrysanthemum plants. In another experiment using urea, NH_4SO_4, NH_4NO_3, $CaNO_3$, and $NaNO_3$, plant growth was best with the NH_4NO_3 applications.

Still, Dirr, and Gartner (1975) also applied different rates of NH_4NO_3 to chrysanthemums grown in fresh and composted barks of four separate species of hardwood trees. Increased N levels resulted in greater plant dry weight in all instances; however, the composted bark levels were significantly greater than the fresh bark. Potted chrysanthemums were also studied in an experiment by Szopa, Hartley, and McGinnes (1973) using various container mixtures of bark from seven different species of hardwood trees. A combination of Magamp with a weekly application of a soluble 20-5-30 fertilizer was used. Plants grown in bark mixes were less succulent and had fewer flowers than comparative peat mixes, but were still of commercial quality.

Plant nutrition is important to growers and researchers. Tissue testing is a useful tool utilized in nutritional experiments. Foliar analysis is based on the uptake and distribution of minerals by plants and a quantitative relation between these absorbed nutrients and growth.

Criley and Carlson (1970) summarize several sources who have done work on establishing optimum and critical threshold of deficiency values for a range of floriculture crops. On a percent dry weight basis, the "critical" level for potted chrysanthemums was noted as being less than 2.4 percent for N, less than 2.8 percent for P, less than .62 percent for K, less than .77 percent for Ca, and less than .14 percent for Mg. Hammer and Boodley are quoted in this same paper as establishing the following optimum levels for the variety Golden Princess Anne: 4.26-5.46 percent for N, .61-.80 percent for P, 6.2 percent for K, 1.23-1.75 percent for Ca, and .53-.57 percent for Mg.

MATERIALS AND METHODS

Representative samples of fresh hardwood bark were obtained from the Groveton Paper Company in Groveton, New Hampshire. The composition of this bark source consisted of approximately 35 percent Sugar Maple (Acer saccharum) 35 percent Yellow Birch (Betual allegheniensis); and 30 percent made up of a combination of American Beech (Fagus grandifolia), White Birch (Betula papyrifera), Basswood (Tilia americana), poplar (Populus tremuloides), Red Maple (Acer rubrum) and Elm (Ulmus americana).

Fresh softwood bark was obtained from the mill of Charles DiPrizio in Union, New Hampshire. It consisted primarily of White Pine (Pinus strobus) and included only about 2 percent by volume of Red Pine (Pinus resinosa) and Scotch Pine (Pinus sylvestris).

Bark was obtained directly from the debarking operation at the respective mills and utilized within three weeks of procurement. The fresh bark was passed through a 1.9-cm screen and used without any other processing.

The chrysanthemum cultivar "Bright Golden Anne" (Chrysanthemum morifolium Ramat) was utilized for all the major experiments. Rooted cuttings were obtained from Stafford Conservatories, Inc., in Stafford Springs, Connecticut.

The initial approach taken in this research project was to evaluate a wide variety of mixtures of bark with vermiculite and perlite to determine if they would support plant growth. The vermiculite used was U.S. No. 2 grade and the perlite was the horticultural grade. Both were obtained from the Terra-lite Horticultural Products Division, W. R. Grace and Company, Cambridge, Massachusetts.

Experiment 1

The first experiment was a broad evaluation of seven different potting mixtures, including a standard greenhouse soil mix and a peat-lite mix. There were four fertilizer treatments. The experiment was designed in a randomized split block design with three replications. One rooted chrysanthemum cutting was planted per 1.4 cm (4½ inch) pot and there were four pots per treatment in each replicate.

The potting media consisted of the following mixtures:

1) 25% hardwood bark and 75% vermiculite
2) 50% hardwood bark and 50% vermiculite
3) 75% hardwood bark and 25% vermiculite
4) 50% hardwood bark and 50% perlite
5) 50% softwood bark and 50% vermiculite
6) 50% peatmoss and 50% vermiculite
7) soil mix (2 parts soil, 1 peat, 1 perlite by volume)

Fertilizer materials consisted of commercially available formulations of the slow-release products Osmocote and Magamp. Osmocote, manufactured by the Sierra Chemical Company, Newark, California, consists of several nutrient formulations enclosed within a multiple semipermeable plastic coating. Osmocote 14-14-14 is a standard three- to four-month release material for short-term crops. It has 8.4 percent ammonium nitrogen derived from ammonium nitrate and ammonium phosphates, 5.6 percent nitrate nitrogen from ammonium nitrate, 14 percent available phosphoric acid derived from ammonium phosphate and calcium phosphate, and 14 percent soluble potash from sulphate of potash. Osmocote 18-6-12 is designed for long-term crops with a projected eight- to nine-month release period and is derived from the same nutrient sources as the 14-14-14 formulation. Magamp is a product of the W. R. Grace Company, Baltimore, Maryland. Magamp's 7-40-6 slow twelve- to twenty-four-week release characteristics come from the low water solubility chemical property of its constituents: magnesium ammonium phosphate and magnesium potassium phosphate.

These materials were incorporated at the time of planting at recommended manufacturers' rates. The fertilizer treatments were as follows:

1) Check - no fertilizer added.

2) 227 gm of 18-6-12 Osmocote per 35 liters of mix (8 oz./bushel).

3) 312 gm of 14-14-14 Osmocote per 35 liters of mix (11 oz./bushel).

4) 284 gm of 7-40-6 Magamp per 35 liters of mix (10 oz./bushel).

The cuttings were planted the week of July 15, 1971. All plants were pinched on August 15 and received artificial light from 10 p.m. until 2 a.m. until September 1. Shading was then applied until bud color was visible. The plants flowered and data were taken during the week of November 20. Data collected consisted of the following:

subjective visual rating for conformity and commercial quality on a scale of 1 to 5, the number of flowers and buds showing color, plant height expressed in centimeters and measured from soil line to top of tallest flower, and fresh weight of plants expressed in grams.

Representative samples of media from each replication were obtained prior to planting. The University of New Hampshire Analytical Services Laboratory conducted tests for percent moisture, dry matter, ash, and organic matter. Samples were weighed, then oven dried for 12 hours at 105 ^{o}C. After weighing again, the samples were ashed for 4 hours at 550 ^{o}C, reweighed and determinations made. A soil test using a modified Morgan technique was also obtained for the bark components and the 50 percent hardwood bark-vermiculite samples from the preplant period and for all the various planting mixtures at the post-harvest period.

Leaf samples were obtained for foliar tissue testing. Up to ten leaves per plant were selected from just above the pinch to just below the first floral cluster. The leaf samples were dried at 80 ^{o}C and spectrographically analyzed for N, P, K, Ca, Mg, Mn, Fe, B , Zn, and Mo using the services of the Ohio Plant Analysis Laboratory, Wooster, Ohio.

Experiment 2

The major objectives of this study were to obtain additional supportive observations on plant growth in various bark media with slow-release fertilizers and to characterize some physical and chemical properties of the media.

The second experiment was a randomized split block design similar to the first trial. One rooted chrysanthemum cutting was planted per 11.4 cm pot. Eight potting mixtures were utilized. There were four fertilizer treatments with four pots per treatment contained in each of three replications.

The potting mixtures evaluated in this experiment consisted of:

1) 50% hardwood bark and 50% vermiculite

2) 75% hardwood bark and 25% vermiculite

3) 100% hardwood bark and 0% vermiculite

4) 50% hardwood bark and 50% perlite

5) 75% hardwood bark and 25% perlite

6) 50% softwood bark and 50% vermiculite

7) 75% softwood bark and 25% vermiculite

8) 50% peatmoss and 50% vermiculite

Fertilizer treatments were:

1) 255 gm of 18-9-0 Osmocote per 35 liters of mix (9 oz./bushel)

2) 227 gm of 18-6-12 Osmocote per 35 liters of mix (8 oz./bushel)

3) 312 gm of 14-14-14 Osmocote per 35 liters of mix (11 oz./bushel)

4) 284 gm of 7-40-6 Magamp per 35 liters of mix (10 oz./bushel)

18-9-9 Osmocote is a three- to four-month release material similar to 14-14-14. The cuttings were planted the week of December 17, 1971, and pinched January 10. The plants were lighted from January 10 to February 1 and were in flower the week of April 10. Observations were made on visual rating, flower number, plant height, plant fresh and dry weights, similar to Experiment 1.

The same physical analyses conducted in Experiment 1 were again performed by the University Analytical Service Laboratory on post-harvest samples; however, soil nutrient tests were not included in the discussion in this experiment because of the difficulties in extraction techniques experienced in the first trial. Spectrographic analysis of selected samples was also conducted for the same elements noted in Experiment 1.

Observations on fresh weight, plant height, and foliar N content were deemed to be most meaningful of the recorded data. The production schedule used in growing the plants and the small pot size were not conducive to the use of other performance criteria. These data were statistically analyzed using the University of New Hampshire computer program TURNIP, which provided an analysis of variance, means, and confidence limits for various differences among means.

In this experiment, samples of potting mixes and their components plus several other commercially available products were subjected to several additional physical test determinations. Seven 20.3-cm (8-inch) screens ranging from a mesh size of 11 mm to 590 microns (including Tyler sizes 3, 6, 9, 12, 16, and 28) were arranged on a mechanical shaker. The percent by weight in grams of the particles retained by various screens was recorded.

Volume weight or bulk density was determined by dividing the weight of the dry medium by the weight of an equal volume of water. A sample consisting of 20 grams of each air dry mixture was placed into a 100-cc graduate cylinder. A rubber stopper piston was held inside the cylinder to prevent the material from bouncing as it was being tapped to settle the contents. After the settled material had reached an equilibrium, the volume that it occupied was recorded. The average of three determinations for each material was used as the volume for that material and an equal volume of water was weighed to make the calculations. Specific gravity is the ratio of the weight of a given volume of a solid substance to the weight of an equal volume of water at 4 ^{o}C. A 250-cc graduate was filled with 100 cc of water. A sample consisting of 10 grams of air dry material was added to the water through a funnel. The material was stirred and allowed to settle so a clear meniscus of the water surface could be read. The total volume of material and water was recorded and the volume of the water displaced by the solid material was calculated. The displaced volume of water also represents the net volume of the solid particles in the 10 grams of material.

The pore space of the materials selected was also determined. The ratio of the specific gravity to the bulk density, when multiplied by 100, becomes the percentage volume of a given volume of material that is occupied by particles. When this percentage is subtracted from 100 percent, the remainder is the percent pore space for the respective material.

Experiment 3

A third experiment designed to explore effects of varying fertilizer rates on a single complete slow-release fertilizer also utilized a randomized split plot. Three rooted chrysanthemum cuttings were planted in a pot 17.8 cm wide and 11.8 cm deep (7-inch azalea pot). There were two potting mixtures and four rates of fertilizers applied as treatments. Four pots comprised each treatment in each of three replications.

The media used in this study were:

1) 50% hardwood bark and 50% vermiculite

2) 75% hardwood bark and 25% vermiculite

Rates of 85, 170, 255, and 340 grams of 14-14-14 Osmocote per 35 liters of mixture (3, 6, 9, and 12 ounces per bushel) were incorporated at planting time.

The cuttings were planted on June 19, pinched June 26, shaded July 17, and flowered the week of September 20, 1972. Plant observations included the number of shoots per plant, plant height, flowers per plant, and fresh and dry weight per plant. The same spectrographic analyses indicated in the earlier experiments were conducted in this study. The same data for the plant growth observations and foliar N were analyzed by computer as indicated in Experiment 2.

Experiment 4

Since N appeared to be a limiting factor in our earlier experiments, a fourth study was devised to determine the effect of N alone upon the growth and development of the test plants.

A randomized split plot design was utilized. One rooted chrysanthemum cutting was planted per 11.4-cm pot. Three potting mixtures were utilized and five fertilizer treatments applied. There were fifteen pots per treatment.

The potting media consisted of the following mixtures:

1) 50% hardwood bark and 50% vermiculite

2) 75% hardwood bark and 25% vermiculite

3) 100% hardwood bark and 0% vermiculite

A stock solution was prepared of each of the five fertilizer concentrations which was applied once a week for 12 weeks at a rate of 108 milliliters (3.6 oz.) per pot.

The fertilizer concentrations were as follows:

1) 100 ppm nitrogen from ammonium nitrate

2) 200 ppm nitrogen from ammonium nitrate

3) 300 ppm nitrogen from ammonium nitrate

4) 400 ppm nitrogen from ammonium nitrate

5) 200 ppm nitrogren from 20-20-20 fertilizer

The cuttings were planted and pinched during the week of November 13, 1972. Lighting of the plants began the same date and continued until the week of December 11. The experiment was terminated during flowering the week of February 5, 1973.

Observations were taken on height per plant, fresh weight and dry weight. The same soil test and spectrographic laboratory analyses were conducted as in the earlier experiments.

Plant height, fresh weight, and foliar N content data were subjected to the same statistical analyses as in earlier experiments.

RESULTS AND DISCUSSION

Experiment 1

Samples of the hardwood and softwood bark components and the seven potting mixtures used in the first broad evaluation experiment were analyzed before planting for pH, percent moisture, ash, and organic matter content. The results are shown in Table 1. In processing and handling, the samples were essentially air dried. The hardwood bark contained 14.5 percent moisture by weight when received by the laboratory, twice the amount recorded for the softwood sample. Less than a .5 percent difference was noted between the hardwood and softwood for organic matter content. The pH for the softwood pine bark was 4.3 and for the blend of hardwood barks the pH was 5.5. This range was similar to findings by other researchers. (Lunt and Clark, 1959; Bollen, 1969; and Gartner (1978). The addition of vermiculite and perlite to the mixtures accounts for the higher pH levels recorded for the various mixes. Perlite has a pH of 7.0 to 7.5. American vermiculite has an average pH of about 7, but African vermiculite sources may range as high as a 9.8 pH.

Random samples of the two raw bark components were submitted for a soil test. Only a trace of nitrogen was found; however, levels of P, K were high. There appeared to be far less Ca in the softwood bark (Table 2). Samples of 50 percent hardwood bark and vermiculite with either 14-14-14 Osmocote or 7-40-6 Magamp incorporated were also tested prior to planting. The analytical test results are shown in Table 2. The depression of pH with the addition of Osmocote can be attributed to the slightly acid reaction of this material, whereas Magamp is neutral. Since none of the inorganic amendments contain P, the level of this element is reduced in the total mixture. The vermiculite does supply some K and Mg. The increase in N content and the differences between the two slow-release fertilizer treatments can be attributed to mechanical breakage of the plastic coating and release of contents during the laboratory preparation of the Osmocote samples.

Table 3 lists the mixtures tested and the report for the media submitted for testing at the conclusion of the experiment. It was determined that a conventional soil test would serve as a rough guideline at best for a critical analysis of these light-weight, highly absorbant materials. Normal extraction ratios of 2-1 would not always work well with the high organic content components and vermiculite combinations. Varying extraction rates up to 6-1 were frequently used by laboratory personnel. The inclusion of the encapsulated and slowly soluble fertilizers also created problems during the drying and screening preparations by the technicians.

Table 4 provides an approximate conversion index for the quantitative terms used in the soil test report to estimated parts per million. Transposition is more accurate at lower nutrient levels than at high levels because the subjective determinations made by laboratory technicians went beyond the accuracy of existing instrumentation and techniques.

Table 1. pH AND PHYSICAL ANALYSES FOR MOISTURE, ASH, AND ORGANIC MATTER OF MIXES IN EXPERIMENT 1.

Description of Sample	pH of Moist Sample	% DRY MATTER as Received at Laboratory	% MOISTURE as Received at Laboratory	% ASH on Moisture Free Basis	% ORGANIC MATTER on Moisture Free Basis
75% Hardwood Bark & 25% Vermiculite	6.4	87.94	12.06	20.38	79.62
50% Hardwood Bark & 50% Vermiculite	6.6	84.09	15.91	45.82	54.18
25% Hardwood Bark & 75% Vermiculite	6.0	95.40	4.60	74.22	25.78
50% Hardwood Bark & 50% Perlite	6.7	99.48	0.52	46.17	53.83
50% Softwood Bark & 50% Vermiculite	5.1	96.08	3.92	38.45	61.55
2 soil, 1 peat, 1 perlite	5.1	97.98	2.02	88.90	11.10
50% Peat Moss & 50% Vermiculite	5.1	94.42	5.58	62.90	34.10
Hardwood Bark	5.5	85.44	14.56	8.99	91.01
Softwood Bark	4.3	92.57	7.43	9.36	90.62

Table 2. PRE-PLANTING SOIL TEST RESULTS FOR THE BARK COMPONENTS AND TWO OF THE HARDWOOD BARK AND VERMICULITE MIXTURES WITH OSMOCOTE AND MAGAMP INCORPORATED USED IN EXPERIMENT 1

Material Tested (Pre-Plant)	Soil Test Results							
	pH	NO_3	NH_4	P	Mg	K	Ca	Soluble Salt K Value
100% Hardwood Bark	5.5	Trace	VL	VH	MH	VH++	VH+	60
100% Softwood Bark	4.3	Trace	VL	VH	H	VH	Trace	26
50% Hardwood Bark & 50% Vermiculite + 14-14-14 Osmocote	5.4	VH++++	VH++++	L	VH	VH++	VH++	699
50% Hardwood Bark & 50% Vermiculite + 7-40-6 Magamp	6.8	L	VH+	VL	VH++	VH++	VH+	320

Table 3. POSTHARVEST SOIL TEST RESULTS FOR THE SEVEN MIXTURES AND FOUR FERTILIZER TREATMENTS USED IN EXPERIMENT 1

Medium Tested	pH	NO_3	NH_4	P	Mg	K	Ca	Soluble Salt K Value
	Soil Test Results							
25% Hardwood Bark & 75% Vermiculite								
+ No fertilizer	6.0	Trace	VL	H	MH	VH+	VH++	27
+ 18-6-12	6.0	H	VH	VH	VH	VH	VH	145
+ 14-14-14	5.7	H	VH+	VH	VH	VH+	VH	395
+ 7-40-6	6.9	Med	VH++	VL	VH+	VH	H	148
50% Hardwood Bark & 50% Vermiculite								
+ No fertilizer	6.6	Trace	VL	VH	H	VH+	VH+	28
+ 18-6-12	4.7	VH++	VH+++	VH	VH	VH++	VH++	455
+ 14-14-14	5.6	VH	L	VH	VH+	H	VH	410
+ 7-40-6	6.2	L	L	L	VH+	VH	VH	178
75% Hardwood Bark & 25% Vermiculite								
+ No fertilizer	6.4	Trace	VL	VH+	Med	VH++	VH++	44
+ 18-6-12	5.1	VH	VH+	VH	MH	VH+	VH+	640
+ 14-14-14	5.3	VH	VH++	VL	VH	VH+	VH	1000+
+ 7-40-6	6.5	H	VH	H	VH	VH	VH	163
50% Hardwood Bark & 50% Perlite								
+ No fertilizer	6.7	Trace	VL	VH	MH	VH++	VH	34
+ 18-6-12	5.0	VH	VH++	VH	MH	VH+	H	1000+
+ 14-14-14	5.3	VH	VH++	Med	MH	VH+	H	950
+ 7-40-6	6.8	Med	VH	VH	VH	VH	H	130
50% Softwood Bark & 50% Vermiculite								
+ No fertilizer	5.1	VL	VL	MH	VH	VH	Med	
+ 18-6-12	5.0	VH	VH++	VH	VH	VH+	Med	360
+ 14-14-14	4.8	VH	VH+	VH+	VH	VH+	L	205
+ 7-40-6	6.5	Med	VH++	VL	VH	VH++	VL	181

(continued)

Table 3 (continued)

Medium Tested	pH	NO_3	NH_4	P	Mg	K	Ca	Soluble Salt K Value
				Soil Test Results				
Soil Mix (2 soil, 1 peat, 1 perlite)								
+ No fertilizer	5.1	H	VL	MH	VH	MH	H	58
+ 18-6-12	4.9	VH	VH++	VH+	H	VH++	VL	340
+ 14-14-14	5.0	VH	VH++	VH+	VH	VH++	VL	321
+ 7-40-6	6.2	VL	VH+	VH	H	VH+	VL	65
50% Peat Moss & 50% Vermiculite								
+ No fertilizer	5.1	Trace	VL	H	VH	Med	VL	21
+ 18-6-12	4.6	VH	VH++	VH	VH	VH++	VH	690
+ 14-14-14	4.5	VH	VH++	H	VH	VH++	Med	580
+ 7-40-6	6.5	Med	VH++	VL	VH	VH++	VL	122

Table 4. UNIVERSITY OF NEW HAMPSHIRE ANALYTICAL LABORATORY TABLE FOR CONVERSION OF QUANTITATIVE SOIL TEST TERMS TO ESTIMATED PARTS PER MILLION

Soil Test Reading	NO_3	NH_4	P	Mg	K	Ca	Soluble Salts K Value
V Low	12	25	0.6	1	50	520	
Low	20	10	3.2	2	70	660	0-50
Medium	40	30	6.4	8	90	800	51-125
High	72	50	16.0	20	150	940	126-175
V High	112	70	40.0	70	250	1080	176-200
V High+	160	90	60.0	150	375	1220	Above 200
V High++	210	110	80.0	250	450	1400	
V High+++	250	130	100.0	375	500	1500	

It did appear, however, that N was the most limiting element where no fertilizer was applied. Bark and/or the other amendments seemed to make some contribution to the supply of other major and secondary elements. For the most part, all of the nutrient elements, other than N still had readings in the high or very high range at the conclusion of the experiment even though no fertilizer had been applied. Magamp did not appear to supply sufficient nutrition in most cases, particularly of N and P.

Plant data taken for the first broad evaluation of seven different potting mixtures commenced during the week of November 20, 1972. Chrysanthemum growth response for those plants produced in 50 percent hardwood bark and 50 percent vermiculite and provided with the same four fertilizer treatments is shown in Figure 2. A similar growth response pattern was noted for all of the potting mixtures. Plants receiving no fertilizer lacked size, vigor and weight and had less foliage and flower color. Plants grown in the soil mixture without fertilizer were slightly better than those produced without fertilizer in the other mixtures because of more residual soil nutrients and less microbial competition for available N.

The criteria utilized to evaluate plant growth and the experimental results are shown in Table 5. In general, the plants grown with 7-40-0 Magamp had fewer flowers on shorter, lighter-weight plants. There did not appear to be any major differences in plant response between the 18-6-12 and 14-14-14 Osmocote formulations. The mixture containing 75 percent hardwood bark produced fewer flowers on somewhat shorter, lighter-weight plants than the other artificial mixes. Some deviations

Figure 1: Growth response of the chrysanthemum cultivar "Bright Golden Anne" grown in 50 percent hardwood bark and 50 percent vermiculite.

Treatments were (from left to right):

no fertilizer

227 gm 18-6-12 Osmocote

312 gm 14-14-14 Osmocote

284 gm 7-40-6 Magamp

incorporated per 35 liters of mix.

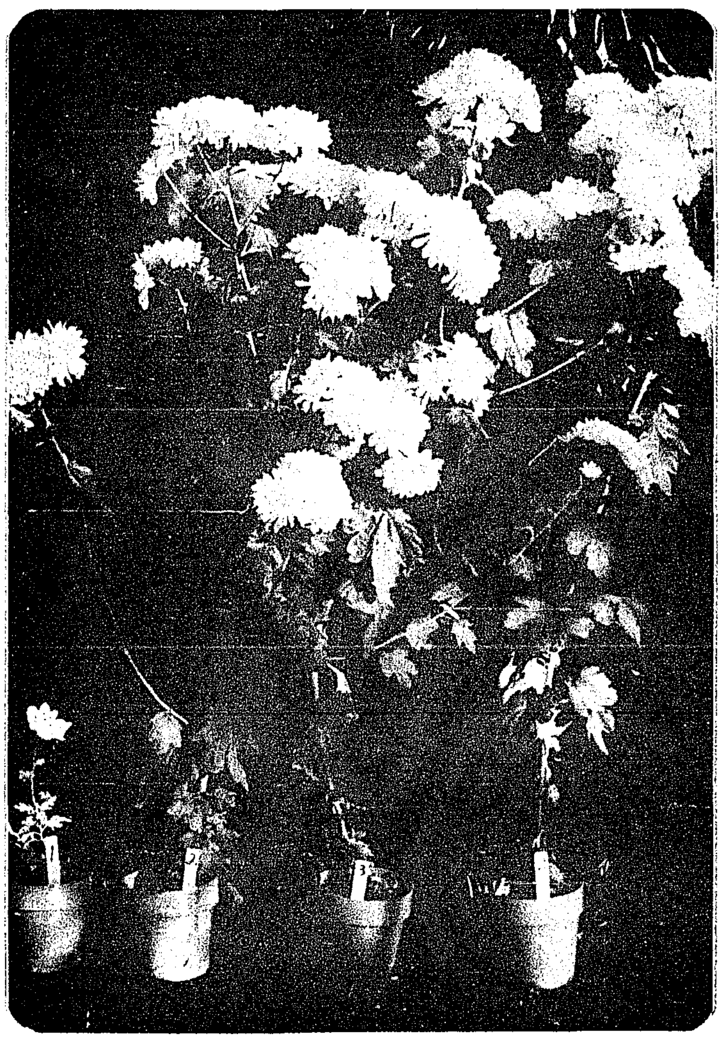

Figure 2: Growth response of the chrysanthemum cultivar, "Bright Golden Anne" grown in 50 percent softwood bark and 50 percent vermiculite.

Treatments were (from left to right):

No fertilizer

227 gm 18-6-12 Osmocote

312 gm 14-14-14 Osmocote

284 gm 7-40-6 Magamp

incorporated per 35 liters of mix.

Table 5. EVALUATION OF PLANTS IN EXPERIMENT 1 FOR VISUAL RATING, FLOWER NUMBER, PLANT HEIGHT, AND FRESH WEIGHT. VALUES REPRESENT MEANS AND STANDARD DEVIATIONS FOR THREE REPLICATIONS

Medium	Fertilizer Treatment	Visual Rating 1 = Poorest 5 = Best	Flower Number	Plant Height (cm)	Fresh Weight (gm)
25% Hardwood Bark & 75% Vermiculite	No Fert.	1.0±.0	1.0±.0	28.8±.6	6.4±.6
	18-6-12	3.3±.2	30.8±3.3	96.9±15.1	226.6±16.5
	14-14-14	3.7±.2	37.4±6.4	101.8±11.0	300.9±61.6
	7-40-6	3.2±.2	22.3±2.6	95.8±5.1	208.3±31.1
50% Hardwood Bark & 50% Vermiculite	No Fert.	1.0±.0	1.0±.0	25.2±1.8	7.32±2.0
	18-6-12	3.1±.5	29.3±5.3	98.6±18.6	223.1±68.5
	14-14-14	3.5±.4	33.5±4.7	94.2±12.8	248.3±40.2
	7-40-6	2.7±.3	13.1±1.0	88.7±8.3	108.9±3.7
75% Hardwood Bark & 25% Vermiculite	No Fert.	1.0±.0	1.0±.0	22.9±4.6	6.7±2.1
	18-6-12	3.0±.9	18.7±8.6	81.9±21.9	164.9±41.0
	14-14-14	3.2±.2	24.6±4.5	84.0±5.8	182.2±6.3
	7-40-6	2.6±.7	16.4±8.6	79.2±3.9	142.45±48.2
50% Hardwood Bark & 50% Perlite	No Fert.	1.0±.0	1.3±.4	27.3±1.9	8.5±2.1
	18-6-12	3.3±.2	25.2±2.5	92.3±11.0	188.8±39.6
	14-14-14	2.9±.1	25.8±4.9	88.9±3.6	188.7±13.1
	7-40-6	2.3±.3	13.4±7.1	79.2±9.1	86.2±28.4
50% Softwood Bark & 50% Vermiculite	No Fert.	1.0±.0	1.7±.6	29.0±3.1	9.9±3.1
	18-6-12	3.3±.1	30.6±.5	102.9±4.2	262.7±6.4
	14-14-14	3.6±.3	30.4±.4	102.2±4.5	263.8±13.3
	7-40-6	2.9±.1	22.6±3.5	103.5±10.4	186.4±14.3
50% Peat & 50% Perlite	No Fert.	1.0±.0	1.2±.2	40.9 1.7	10.6 2.7
	18-6-12	3.5±.2	30.7±.1	98.9 13.6	211.2 26.6
	14-14-14	3.3±.1	33.1±.8	89.9 4.9	236.3 4.5
	7-40-6	3.1±.2	23.4±3.3	95.9 1.6	223.3 47.9

(continued)

Table 5 (continued)

Medium	Fertilizer Treatment	Visual Rating 1 = Poorest 5 = Best	Flower Number	Plant Height (cm)	Fresh Weight (gm)
Soil Mix	No Fert.	1.0±.0	3.0±.36	61.8±2.6	20.1±8.7
	18-6-12	3.3±.5	25.7±8.1	101.4±8.1	210.3±60.9
	14-14-14	3.3±.4	29.4±5.9	96.5±6.6	231.4±62.1
	7-40-6	2.3±.3	21.2±14.3	79.6±14.3	61.3±5.8

of plant height and fresh weight within the same mixture and treatment may have been caused by shading created by close plant spacing.

Visual differences were noted in the apparent size and vigor of the root systems of soil-grown plants and those produced in bark or peat media. In the soil mix the roots formed a solid network against the pot wall. Those root systems in bark and peat appeared to have a finer root system dispersed more uniformly throughout the root ball; better aeration and drainage in the artificial media is the probable explanation. Such a root system should make better use of water and nutrient supplies and reduce some environmental stress.

Spectrographic analyses of composite random foliage samples of chrysanthemum test plants were conducted. Table 6 presents the findings for ten elements deemed to be the most important for chrysanthemum growth. The tissue of plants receiving no fertilization were well below the critial level for N and were showing visible symptoms of nutrient deficiency. Most plants from other treatments were approaching that same level but were normal in appearance. Criley and Carlson (1970) identified the critical level for potted chrysanthemums as 2.4 percent N and mentioned an optimal level of between 4.3 and 5.7 percent N. None of the treatments in any of the mixes were in the optimum N range. Levels for P were approaching the critical level for that element in the mixtures that received either no fertilizer or the 18-6-12 Osmocote. The other mixture and fertilizer combinations were within the optimum range for P. All of the mixes and fertilizer treatments produced levels of K within the optimum range for that element. Ca was below the critical level in the soil mix and Magamp

Table 6. FOLIAR ANALYSIS REPORT OF PLANTS GROWN WITH THE VARIOUS MIXES AND FERTILIZER TREATMENTS IN THE FIRST TRIAL. TISSUE ANALYSIS REPORT OF THE AMOUNT OF N, P, K, Ca, Mg, Fe, Bo, Zn, and Mo FOUND IN THE LEAVES OF CHRYSANTHEMUMS GROWN WITH THE SEVEN MIXTURES AND FOUR FERTILIZER TREATMENTS IN EXPERIMENT 1

Medium	N	P	K	Ca	Mg	Mn	Fe	B	Zn	Mo
	%					ppm				
				No Fertilizer Added						
25% Hardwood Bark + 75% Vermiculite	.50	.27	2.63	1.83	.50	121	175	62	95	4.35
50% Hardwood Bark + 50% Vermiculite	.65	.26	3.14	1.67	.38	175	208	70	150	1.42
75% Hardwood Bark + 25% Vermiculite	.60	.53	4.79	3.41	.88	411	754	152	150	13.46
50% Hardwood Bark + 50% Perlite	1.80	.36	3.62	1.91	.37	317	162	69	133	1.25
50% Softwood Bark + 50% Vermiculite	1.30	.50	3.19	2.01	.49	253	197	63	67	2.43
Soil Mix (2 soil, 1 peat, 1 perlite)	.95	.28	2.90	1.45	.47	447	330	47	71	1.53
50% Peat + 50% Vermiculite	.65	.25	3.23	1.25	.36	203	174	46	94	1.50

(continued)

Table 6 (continued)

Medium	N	P	K	Ca	Mg	Mn	Fe	B	Zn	Mo
	%					ppm				
					18-6-12 Added					
25% Hardwood Bark + 75% Vermiculite	3.75	.30	3.38	1.89	.53	330	215	22	58	1.68
50% Hardwood Bark + 50% Vermiculite	2.65	.33	3.49	2.15	.40	361	333	42	131	3.09
75% Hardwood Bark + 25% Vermiculite	2.80	.35	3.37	2.51	.45	425	368	39	172	3.01
50% Hardwood Bark + 50% Perlite	2.75	.32	1.45	3.20	.65	479	225	37	124	3.38
50% Softwood Bark + 50% Vermiculite	2.95	.28	3.22	1.32	.43	271	269	20	89	1.29
Soil Mix (2 soil, 1 peat, 1 perlite)	1.60	.24	4.28	.98	.52	115	155	42	52	1.53
50% Peat + 50% Vermiculite	3.05	.30	2.98	1.34	.60	174	318	20	52	1.83
					14-14-14 Added					
25% Hardwood Bark + 75% Vermiculite	2.35	.82	3.83	1.33	.31	348	256	24	47	1.82
50% Hardwood Bark + 50% Vermiculite	2.15	.98	3.70	1.64	.23	414	357	34	76	2.61
75% Hardwood Bark + 25% Vermiculite	2.45	.74	3.34	1.63	.18	379	213	33	74	.79

(continued)

Table 6 (continued)

Medium	N	P	K	Ca	Mg	Mn	Fe	B	Zn	Mo
	%					ppm				
50% Hardwood Bark + 50% Perlite	2.65	1.17	2.75	2.27	.47	486	238	35	93	1.90
50% Softwood Bark + 50% Vermiculite	2.85	1.03	3.46	1.35	.40	301	460	25	62	1.97
Soil Mix (2 soil, 1 peat, 1 perlite)	3.35	.41	2.19	1.28	.51	447	271	21	62	1.89
50% Peat + 50% Vermiculite	2.35	.64	3.50	1.59	.52	220	252	23	60	1.48
					7-40-6 Added					
25% Hardwood Bark + 75% Vermiculite	2.75	.29	1.64	1.12	.42	425	202	19	65	.78
50% Hardwood Bark + 50% Vermiculite	1.85	1.21	3.24	1.31	.78	105	264	62	69	4.78
75% Hardwood Bark + 25% Vermiculite	2.20	1.32	3.16	1.32	.84	147	167	52	110	3.75
50% Hardwood Bark + 50% Perlite	2.60	1.50	1.67	1.72	1.12	163	220	62	83	3.22
50% Softwood Bark + 50% Vermiculite	2.15	1.19	3.29	1.12	.74	86	252	42	48	6.01
Soil Mix (2 soil, 1 peat, 1 perlite)	2.70	.86	1.79	.53	.99	359	252	50	52	3.15
50% Peat + 50% Vermiculite	1.55	.94	3.39	.99	.72	116	265	34	36	2.74

combination; but for the majority of mixes Ca content was in the optimum range. Tissue levels for Mg, Mn, Fe, B , Zn, and Mo were all in the optimum range for all mixtures and treatments.

Experiment 2

Some visual differences were noted between the two samples utilized in these experiments. The hardwood bark was obtained from a wet drum debarking process, while the softwood pine bark came from a mill using a rosser-head debarker. It was estimated that the hardwood bark residue contained up to 10 percent wood. Considerably more wood was observed in the supply of softwood bark.

In the initial screening of the bark prior to mixing with other growing mix components, it was noted that a portion of narrow slivers of pine bark up to about six centimeters in length were passing lengthwise through the 1.9 cm mesh screen. This created a coarser appearing material. Large fibrous strips of Yellow and White Birch bark did not pass through the screen and therefore reduced the amount of these species contained in the final bark blend used.

The range of bark particle sizes and selected growing media and their components, and several other comparative commercial products were recorded and shown in Table 7.

The size and distribution of particles and their distribution influence surface-to-volume ratios and interspatial properties and, in turn, capacity, moisture retention, aeration, and drainage. Several researchers, Porkorny and Perkins (1967), Gartner, Hughes,

Table 7. PERCENT BY WEIGHT OF PARTICLES IN EACH OF 18 MATERIALS RETAINED IN PROGRESSIVELY SMALLER SCREEN SIZES

Materials Tested	Screen Sizes[a] 1	2	3	4	5	6	7	8
Raw, fresh hardwood bark	44.1	18.9	18.9	5.9	3.5	2.7	2.9	3.1
Screened, fresh hardwood bark	1.3	24.5	44.6	11.1	6.8	4.1	3.9	5.2
Screened, shredded hardwood bark	.7	21.3	31.0	18.1	8.0	6.6	5.6	8.7
1 year composted raw hardwood bark	3.9	12.8	27.6	19.2	19.2	13.8	3.3	.2
1 year composted screened hardwood bark	1.0	26.1	41.5	12.8	5.5	3.9	4.0	5.2
N.Y. commercial shredded hardwood bark	.9	4.1	41.5	10.9	10.6	9.8	9.2	13.0
N.H. commercial composted hardwood bark	1.0	10.6	26.2	18.4	21.5	14.1	6.3	1.9
Screened, fresh softwood bark	2.3	6.3	23.9	31.8	15.3	7.4	6.3	6.8
Screened, shredded softwood bark	.7	11.6	34.0	21.6	11.2	7.5	6.7	6.7
2 soil, 1 coarse peat, 1 perlite mix	.2	1.7	5.4	11.1	5.7	5.6	10.6	59.7
50% coarse peat, 50% vermiculite	2.8	4.9	9.1	27.3	18.9	10.5	11.2	15.4
Vermiculite	0	.1	21.3	52.5	15.2	5.8	3.5	1.6
Perlite	0	0	50.3	38.5	3.8	1.3	.8	5.4
75% hardwood bark, 25% vermiculite	.7	9.8	27.5	27.7	14.5	8.3	7.4	4.2
50% hardwood bark, 50% vermiculite	.4	6.5	23.1	30.8	14.6	7.3	7.3	10.1
50% hardwood park, 50% perlite	1.0	8.7	19.3	23.7	22.7	11.1	5.3	8.2
50% softwood bark, 50% vermiculite	1.1	4.0	20.7	30.5	16.1	8.0	8.0	11.5
Commercial 50% peat, 50% vermiculite	0	0	1.3	6.6	45.5	28.1	13.2	5.3

a - screen sizes were as follows:

1 - .43 inches		11.1 mm opening	
2 - .26 inches	(#3 Tyler)	6.67 mm opening	
3 - .13 inches	(#6 Tyler)	3360 microns	
4 - .08 inches	(#9 Tyler)	2000 microns	
5 - .05 inches	(#12 Tyler)	1410 microns	
6 - .04 inches	(#16 Tyler)	1000 microns	
7 - .02 inches	(#28 Tyler)	590 microns	
8 - bottom pan			

and Klett (1972) and Gartner, Still, and Klett (1975) proposed particle distribution ranges in which they recorded the best growth of container grown ornamental plants. A theoretical optimum particle distribution range based on a composite of their work is included in Table 8 along with the actual particle distribution of some of the bark and other media used in these experiments. Most of the bark based mixes used are close to the mid-range of optimum values but have a higher percentage of coarser particles and lower proportion of desired smaller size particles.

Some additional data on physical properties of the mixes and components used in these experiments is shown in Table 9. Determinations for bulk density or volume weight, specific gravity, and percent pore space are presented. The data are similar to that obtained by Scott and Bearce (1972); however, the blend of New Hampshire tree barks had a slightly lower bulk density weight for the raw bark samples. The relationship of pore space to actual drainage or capillary moisture retention is quite complex. The number and distribution of large and small pores is important in the ultimate performance of a medium. Spoomer (1975) indicated that the amendment of a container medium with coarse-textured materials could increase the number of large "aeration pores" that would drain despite the perched water table.

The initial growth and early stages of development of the chrysanthemum cuttings were curtailed in the coarser textured 100 percent hardwood bark, hardwood bark and perlite, and all the softwood bark

Table 8. PARTICLE SIZE DISTRIBUTION RANGES FOR BARK COMPONENTS AND GROWING MIXTURES

	Particle Size		
Components and Mixes	% Particles More Than 3.2 mm	% Particles Between 3.2 mm & .8 mm	% Particles Less Than .8 mm
Comparative Calculated Theoretical Mix[a]	10 - 20	55 - 60	20- 35
Screened, Fresh Hardwood Bark	70.4	20.5	9.1
Screened, Fresh Softwood Bark	32.9	54.0	13.1
Soil Mixture	7.3	22.4	70.3
50% Peat, 50% Vermiculite	16.8	56.6	26.6
75% Hardwood Bark, 25% Vermiculite	38.0	50.4	11.6
50% Hardwood Bark, 50% Vermiculite	30.0	42.6	17.4
50% Hardwood Bark, 50% Perlite	29.0	57.5	13.5
50% Softwood Bark, 50% Vermiculite	25.8	55.7	18.5

[a]Composite of proposed ideal particle distribution range for container media from Porkorny and Perkins (1967), Gartner, Hughes, and Klett (1972), and Gartner, Still, and Klett (1975).

Table 9. BULK DENSITY, SPECIFIC GRAVITY AND PERCENT PORE SPACE CALCULATED FOR COMPONENTS AND MIXTURES USED IN EXPERIMENTS 1 AND 2 PRIOR TO PLANTING

Components and Mixtures	Bulk Density (g/mℓ)	Specific Gravity (wet)	Percent Pore Space
100% Hardwood Bark	.250	.714	65.0
75% Hardwood Bark, 25% Vermiculite	.227	.667	66.0
50% Hardwood Bark, 50% Vermiculite	.207	.500	58.6
25% Hardwood Bark, 75% Vermiculite	.202	.500	59.6
75% Hardwood Bark, 25% Perlite	.209	.588	64.5
50% Hardwood Bark, 50% Perlite	.235	.625	62.4
100% Softwood Bark	.178	.556	68.0
75% Softwood Bark, 25% Vermiculite	.179	.500	64.2
50% Softwood Bark, 50% Vermiculite	.191	.556	65.6
50% Peat Moss, 50% Vermiculite	.105	.333	68.5
Perlite	.143	.385	62.9
Vermiculite	.096	.333	71.2
Soil Mix (2 soil, 1 peat, 1 perlite)	.359	.909	60.5

mixtures. Once the plants became established and the root system utilized the entire volume of the container, growth evened out and final observations were not as conclusive. Early growth appeared to be best in mixtures which had 50 percent or more vermiculite. The smaller particle sizes and water absorptive property of vermiculite may have fostered better initial development. Difficulty in initial wetting and excessive drainage of pine bark media was observed by Natarella and Porkorny (1978).

The results of the analytical tests for organic matter, percent ash, and moisture content for the various growing mixes evaluated in the second experiment are found in Table 10. These samples were obtained and tested after plant growth was terminated. Procedures similar to those outlined in Experiment 1 were followed for the determination of these values. In comparing the pre-plant percentages of organic matter determined in Experiment 1 with the results for the same mixtures taken during the post-harvest period in Experiment 2, it appears that there were approximate net differences of 10 percent in the 75 percent hardwood bark-vermiculite mix, 1.5 percent in the 50 percent hardwood bark-vermiculite mix, 7 percent in the hardwood bark-perlite mix, and 7 percent for the 50 percent softwood-vermiculite mix. Either the organic matter content was less for the bark components used in Experiment 2 or there was a reduction of organic matter during the three-month plant-growth period.

The evaluation of plant growth in the eight potting mixes and the response to four fertilizer treatments were observed during the week of April 10, 1972. The growth of the chrysanthemum test plants grown

Table 10. THE PERCENT MOISTURE, ASH, AND ORGANIC MATTER FOUND IN VARIOUS MIXES AFTER PLANT GROWTH IN EXPERIMENT 2

Treatment	% MOISTURE as Received at Laboratory	% ASH on Moisture Free Basis	% ORGANIC MATTER on Moisture Free Basis
100% Hardwood Bark			
+ 18-9-9	8.4	2.2	97.8
+ 18-6-12	7.6	10.4	89.6
+ 14-14-14	6.9	10.4	89.6
+ 7-40-6	7.9	11.4	88.6
75% Hardwood Bark & 25% Vermiculite			
+ 18-9-9	7.3	32.4	67.6
+ 18-6-12	7.3	29.0	71.0
+ 14-14-14	7.5	30.4	69.6
+ 7-40-6	8.2	31.1	68.9
50% Hardwood Bark & 50% Vermiculite			
+ 18-9-9	7.1	48.6	51.4
+ 18-6-12	6.6	43.6	56.4
+ 14-14-14	6.9	41.2	55.8
+ 7-40-6	7.4	49.2	50.8
50% Hardwood Bark & 25% Perlite			
+ 18-9-9	5.4	36.9	63.1
+ 18-6-12	5.4	38.1	61.9
+ 14-14-14	5.5	33.9	66.1
+ 7-40-6	5.9	41.3	58.7
50% Softwood Bark & 50% Vermiculite			
+ 18-9-9	5.2	50.7	49.3
+ 18-6-12	5.7	46.5	53.5
+ 14-14-14	6.5	44.7	55.3
+ 7-40-6	6.8	46.5	53.5

(continued)

Table 10 (continued)

Treatment	% MOISTURE as Received at Laboratory	% ASH on Moisture Free Basis	% ORGANIC MATTER on Moisture Free Basis
75% Softwood Bark & 25% Vermiculite			
+ 18-6-12	7.8	22.4	77.6
+ 14-14-14	8.1	28.3	71.7
+ 7-40-6	8.2	27.1	72.9
50% Peat Moss & 50% Vermiculite			
+ 18-9-9	7.2	55.1	44.9
+ 18-6-12	6.9	49.4	50.6
+ 14-14-14	6.5	52.3	47.7
+ 7-40-6	8.7	54.8	45.2

in 50 percent hardwood bark and 50 percent vermiculite is shown in Figure 3. The growth response in the comparative 50 percent peatmoss and 50 percent vermiculite mixture is shown in Figure 4.

It was determined that there was a significant interaction effect between the main effect for mixes and the main effect for fertilizers. The analysis of variance for plant height is found in Table 11a. The means of three replications for plant height expressed in centimeters and the least significant differences for comparisons within groups and between groups is found in Table 11b. The analysis of variance for plant fresh weight is shown in Table 12a and the respective means expressed in grams and the least significant differences for fresh weight are presented in Table 12b. The analysis of variance for foliar nitrogen content is in Table 13a and the means for foliar nitrogen expressed in percent and the least significant difference for comparisons are found in Table 13b.

The plant response to Magamp fertilization was generally not as good to the various formulations of Osmocote with hardwood mixes. Magamp produced plants significantly reduced in size with 75 percent and 100 percent bark plus vermiculite, 50 percent and 75 percent bark plus perlite, and 50 percent bark plus vermiculite with 14-14-14 and the peat mix with 14-14-14. However, with softwood combinations there was no difference between fertilizer treatments. The lack of differences may have been due to the slower decomposition of pine bark and corresponding lighter demands put upon soil N content as proposed by Lunt and Clark (1959), Allison and Klein (1961), and Bollen (1969).

Figure 3: Growth response of chrysanthemum cultivar "Bright Golden Anne" grown in 50 percent hardwood bark and 50 percent vermiculite.

Treatments were (from left to right):

225 gm 18-9-9 Osmocote

227 gm 18-6-12 Osmocote

312 gm 14-14-14 Osmocote

284 gm 7-40-6 Magamp

incorporated per 35 liters of mix.

FIGURE 4.

Growth response of chrysanthemum cultivar 'Bright Golden Anne' grown in 50% peatmoss and 50% vermiculite.

Treatments were (from left to right):

255 gm 18-9-9 Osmocote,

227 gm 18-6-12 Osmocote,

312 gm 14-14-14 Osmocote, and

284 gm 7-40-6 Magamp

incorporated per 35 liters of mix.

Table 11a. ANALYSIS OF VARIANCE FOR PLANT HEIGHT IN EXPERIMENT 2

Source of Variation	DF	Mean Square
Reps	2	1064.3
Mixes	7	347.9
Error A	14	53.9
Fertilizers	3	961.7
Interaction	21	75.3
Error B	48	27.8

Table 11b. THE MEANS OF PLANT HEIGHT EXPRESSED IN CENTIMETERS FOR COMBINATION LEVELS OF MIXES AND FERTILIZERS

	Fertilizer Treatment			
Growing Medium	18-9-9	18-6-12	14-14-14	7-40-6
50% Hardwood Bark and Vermiculite	56.5	57.9	62.1	50.5
75% Hardwood and Vermiculite	57.3	51.3	53.3	35.3
100% Hardwood Bark	50.3	50.5	50.2	29.5
50% Hardwood Bark and Perlite	54.5	52.7	54.1	37.4
75% Hardwood Bark and Perlite	55.2	55.2	50.9	29.2
50% Softwood Bark and Vermiculite	58.8	57.5	60.7	56.9
75% Softwood Bark and Vermiculite	58.1	58.6	55.2	51.2
50% Peat and Vermiculite	53.1	60.1	66.8	56.0

The LSD for comparisons of means within a group is 8.7.
The LSD for comparisons of means between groups is 9.9.
All LSD's at .05 level.

Table 12a. ANALYSIS OF VARIANCE FOR FRESH WEIGHT OF PLANTS IN EXPERIMENT 2

Source of Variation	DF	Mean Square
Reps	2	1585.0
Mixes	7	5368.6
Error A	14	1364.6
Fertilizers	3	37452.0
Interaction	21	1381.3
Error B	48	571.2

Table 12b. THE MEANS OF FRESH WEIGHT EXPRESSED IN GRAMS FOR COMBINATION OF LEVELS OF MIXES AND FERTILIZERS

	Fertilizer Treatments			
Growing Medium	18-9-9	18-6-12	14-14-14	7-40-6
50% Hardwood Bark and Vermiculite	187.9	139.1	199.1	86.3
75% Hardwood Bark and Vermiculite	134.8	118.5	161.4	39.1
100% Hardwood Bark	120.1	103.4	138.1	30.0
50% Hardwood Bark and Perlite	145.0	125.7	188.8	45.2
75% Hardwood Bark and Perlite	137.4	114.1	133.8	35.8
50% Softwood Bark and Vermiculite	146.4	137.8	176.7	101.6
75% Softwood Bark and Vermiculite	165.0	145.6	172.0	102.5
50% Peat and Vermiculite	146.9	147.5	147.9	153.2

The LSD for comparisons of means within a group is 39.3.
The LSD for comparisons of means between groups is 46.9.
All LSD's at .05 level.

Table 13a. ANALYSIS OF VARIANCE FOR FOLIAR NITROGEN CONTENT FOR SELECTED PLANTS IN EXPERIMENT 2

Source of Variation	DF	Mean Square
Reps	2	1.0
Mixes	4	.6
Error A	8	.5
Fertilizers	3	3.8
Interaction	12	.5
Error B	30	.2

Table 13b. THE MEANS OF PERCENT PLANT NITROGEN CONTENT FOR COMBINATION OF LEVELS OF MIXES AND FERTILIZERS.

	Fertilizer Treatments			
Growing Medium	18-9-9	18-6-12	14-14-14	7-40-6
50% Hardwood Bark and Vermiculite	3.5	3.7	3.5	3.0
75% Hardwood Bark and Vermiculite	3.6	4.1	3.6	3.6
100% Hardwood Bark	3.7	4.2	4.0	2.8
50% Softwood Bark and Vermiculite	3.8	4.3	3.5	2.8
50% Peat and Vermiculite	5.2	4.7	3.5	3.1

The LSD for comparisons of means within a group is .7.
The LSD for comparisons of means between groups is .9.
All LSD's at .05 level.

The same pattern for Magamp existed for fresh weight as with plant height, except in this case the only mixture in which it did not produce significantly lighter weights was with the peat mix. The 14-14-14 formulations of Osmocote always produced significantly heavier plants than 18-6-12 in 50 percent and 75 percent hardwood vermiculite and 50 percent perlite combinations. There were no significant differences in any of the fertilizer treatments for 50 percent and 75 percent hardwood bark with vermiculite for foliar N; however, in 100 percent bark, Magamp-treated plants had significantly less foliar N. For the softwood bark 18-9-9 and 18-6-12 Osmocote resulted in improved foliar N as compared with the 7-40-6 Magamp, and the 18-6-12 was better than the 14-14-14 Osmocote formulation.

When the main effect for mixes was examined separately, 50 percent hardwood bark and vermiculite produced significantly taller and heavier plants than 75 percent hardwood bark with either vermiculite or perlite and the 100 percent hardwood bark. There was no significant differences at all in foliar N content. If the main effect for fertilizers was considered alone, all the Osmocote formulations were better than Magamp for height, fresh weight and foliar N content. The 18-9-9 and 14-14-14 were significantly better than the 18-6-12 and the 14-14-14 better than the 18-9-9 for fresh weight. For foliar N, the 18-6-12 was significantly better than the 14-14-14.

Experiment 3

The third experiment was designed to determine the impact of rates of a single type of a slow-release material on plant growth. Osmocote 14-14-14 was selected for use in this trial. Growing mixtures of 50 percent and 75 percent hardwood bark with vermiculite were selected because of an apparent need for slightly more N than with mixes of softwood bark. An important determination was the actual rate of Osmocote that could provide sufficient N for any deficiencies created by the medium and still promote good plant growth. The rates of slow-release fertilizers used for previous experiments were derived from the basic manufacturer's label recommendations. The stated rates for these different formulations were based primarily on use in amended mineral soils. Slightly different rates were given for the use of Osmocote for either light, coarse textures, well-drained soils or for heavier medium-textured, moderately drained soils.

The analysis of variance Tables 14a, 15a and 16a revealed that there was no significant interaction effect between mixes and fertilizer rates for plant height, fresh weight, and for foliar N content, respectively, in the plants. The means reflecting these analyses are found in Tables 14b, 15b, and 16b, respectively.

Observations on plant development and an evaluation of the data indicated the 75 percent bark mix produced shorter plants than the 50 percent bark mixture. A higher content of bark and subsequent need for more nitrogen appeared to curtail growth. There was a significant increase in plant height noted for the 170 gm application

Table 14a. ANALYSIS OF VARIANCE FOR PLANT HEIGHT IN EXPERIMENT 3

Source of Variation	DF	Mean Square
Reps	2	3.2
Mixes	1	61.9
Error A	2	1.1
Fertilizer	3	28.8
Interaction	3	4.0
Error B	12	2.9

Table 14b. THE MEANS FOR PLANT HEIGHT EXPRESSED IN CM FOR PLANTS GROWN IN TWO MIXES EACH WITH FOUR FERTILIZER TREATMENTS OF EXPERIMENT 3

Mixes	Mean Plant Height (cm)
50% Hardwood Bark	55.7
75% Hardwood Bark	52.5
LSD_{05}	1.9
Fertilizer Rates	
85 gm	51.0
170 gm	55.6
255 gm	55.7
340 gm	54.0
$LSD_{.05}$	2.1

Table 15a. ANALYSIS OF VARIANCE FOR FRESH WEIGHT OF PLANTS EXPRESSED IN GRAMS FOR EXPERIMENT 3

Source of Variation	DF	Mean Square
Reps	2	232.3
Mixes	1	2816.6
Error A	2	38.1
Fertilizers	3	21960.3
Interaction	3	715.0
Error B	12	262.6

Table 15b. THE MEANS FOR FRESH WEIGHT EXPRESSED IN GRAMS FOR PLANTS GROWN IN THE TWO MIXES AND WITH THE FOUR FERTILIZER TREATMENTS OF EXPERIMENT 3

Mixes	Mean Plant Weight (gm)
50% Hardwood Bark and Vermiculite	145.5
75% Hardwood Bark and Vermiculite	123.8
LSD_{05}	10.8
Fertilizer Treatments	
85 gm	54.4
170 gm	123.5
255 gm	169.8
340 gm	191.0
$LSD_{.05}$	20.4

Table 16a. ANALYSIS OF VARIANCE FOR PERCENT NITROGEN CONTAINED IN THE FOLIAGE OF PLANTS GROWN IN EXPERIMENT 3

Source of Variation	DF	Mean Square
Reps	7	.09
Mixes	1	.07
Error A	7	.03
Fertilizer	3	2.61
Interaction	3	.10
Error B	42	.04

Table 16b. THE MEANS FOR PERCENT NITROGEN CONTAINED IN THE LEAVES OF PLANTS GROWN IN THE TWO MIXES AND WITH THE FOUR FERTILIZER TREATMENTS OF EXPERIMENT 3

Mixes	% N
50% Hardwood Bark and Vermiculite	2.4
75% Hardwood Bark and Vermiculite	2.5
LSD_{05}	.2
Fertilizer Treatments	
85 gm	1.9
170 gm	2.4
255 gm	2.6
340 gm	2.9
$LSD_{.05}$	.1

rate over the 85 gm rate, indicating that the microbial demands may have been met at the 170 gm rate. There were other significant differences between rates of 170 gm, 255 gm, and 340 gm in regard to stimulation of plant height (Figure 5).

There was a significant difference between the fresh weights of plants grown in the 50 percent and 75 percent bark mixes. The heavier fresh weight for the 50 percent bark again appeared to be related to N. Another possibility might be that the larger amount of vermiculite in the 50 percent bark medium contributed more particle fines and thus better moisture or cation exchange capacity along with more K and Mg. Each successively increased rate of fertilizer application had a significant impact. The 340-gm rate of Osmocote-treated plants were more than three times the fresh weight of the lowest 85-gm rate (Figure 6).

There was no significant difference between bark mixes in regard to the percent of N found in the leaves of the test plants. A uniform correlation existed for increased rates of fertilizer and increased N content of the leaves. Significant increases were noted in foliar N content for each progressively higher fertilization rate (Figure 7).

In general, the 85-gm and the 170-gm rates of fertilizer were not as satisfactory as the 255-gm and 340-gm rates of Osmocote 14-14-14 in promoting good growth. Plants produced with the two lower rates had an N content at or below the critical level of 2.4 percent mentioned in Experiment 2. The maximum rate for satisfying the N deficiency of decomposing hardwood bark and optimizing plant growth may be well beyond the 340 gm per 35 liter of mix incorporation rate. The 340-gm

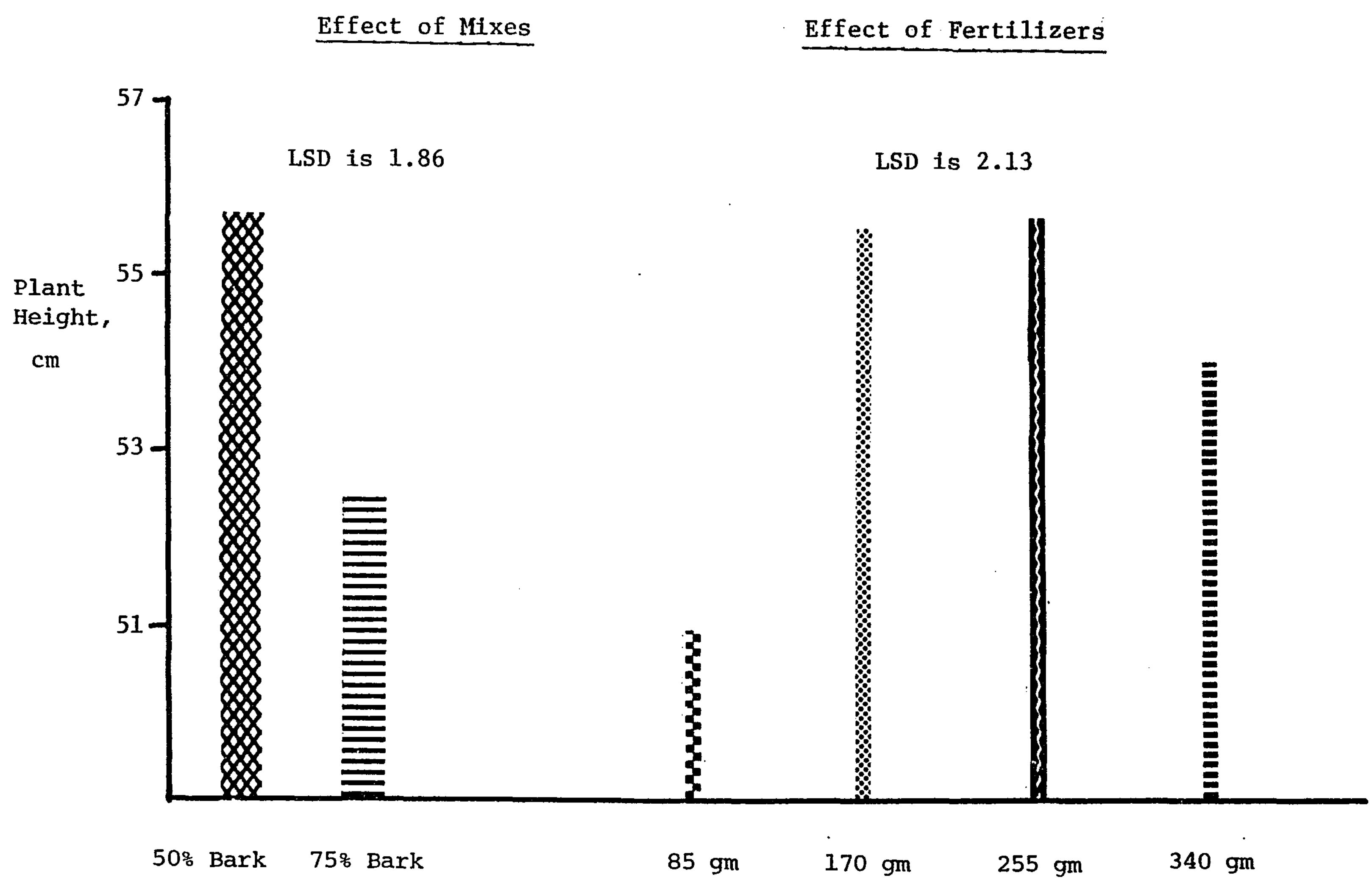

Figure 5. The main effect means for mixes and fertilizers for plant height expressed in terms of centimeters for plants in Experiment 3.

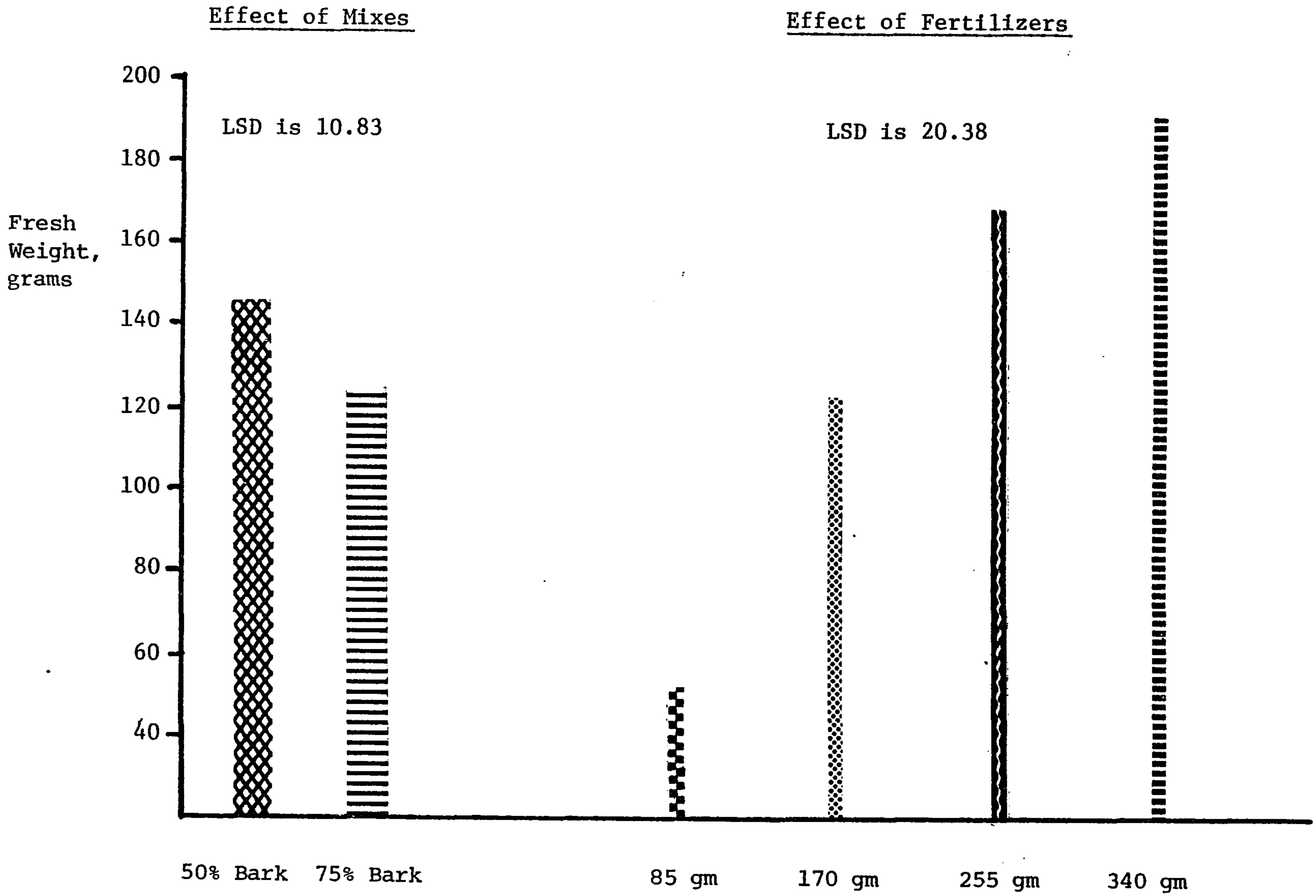

Figure 6. The main effect means for mixes and fertilizers for fresh weight expressed in grams for plants in Experiment 3.

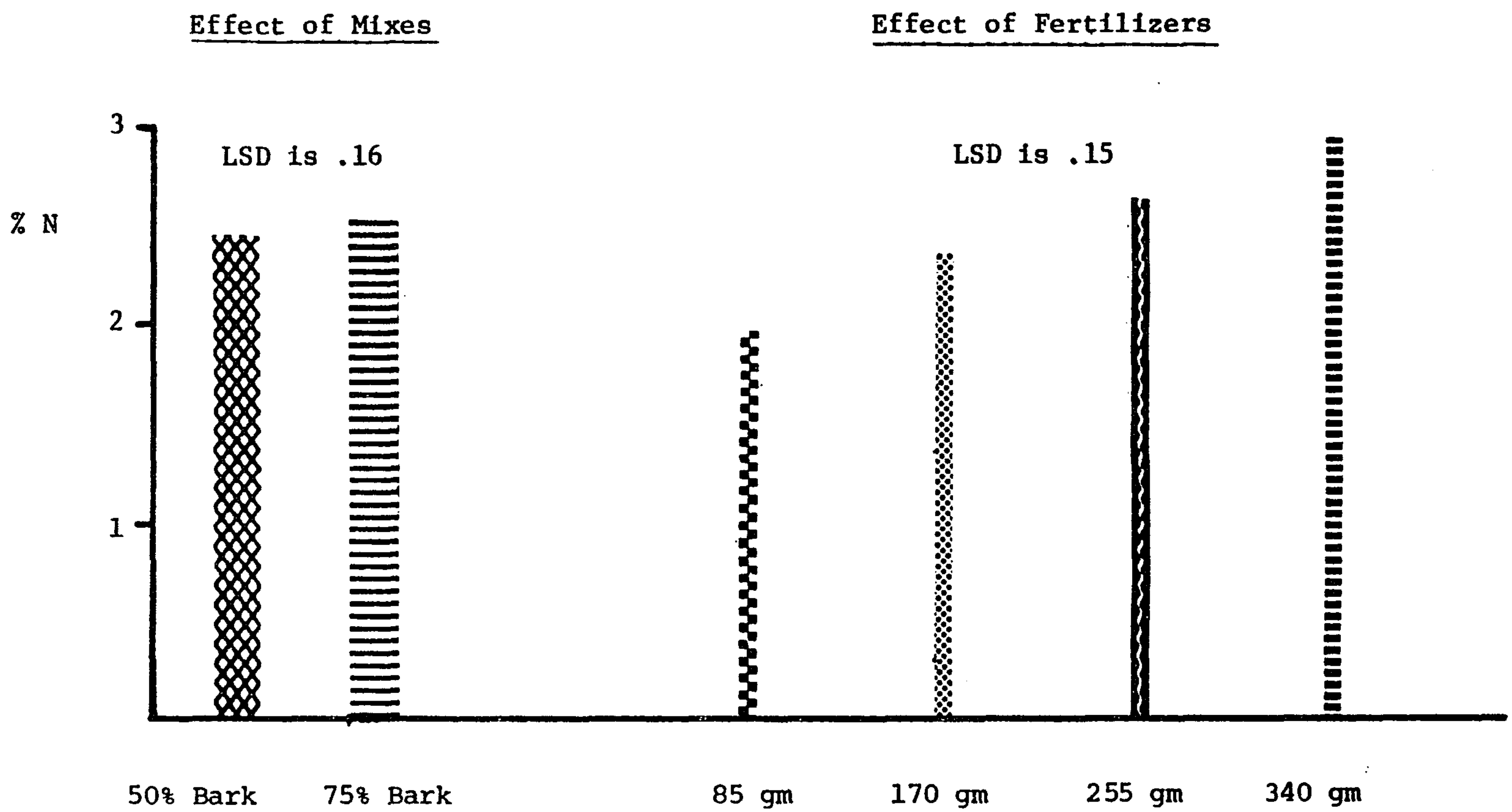

Figure 7. The main effect means for mixes and fertilizers for the percent nitrogen contained in the foliage of plants in Experiment 3.

rate grown plants only had an N content of 2.9 percent, about half of the suggested optimal content for the cultivar of chrysanthemum.

Experiment 4

The primary objective of this study was to determine the effect of differenct rates of an N source upon plants grown in mixtures of 50 percent, 75 percent and 100 percent hardwood bark.

The importance of N was evident in earlier experiments. The effect of varying amounts of a slow-release complete fertilizer was noted in the third experiment. The purpose here was to determine if weekly applications of a soluble N fertilizer; such as ammonium nitrate, could offset N demands of the bark and still provide N for crop growth. Four rates, 100, 200, 300, and 400 parts per million N, all derived from ammonium nitrate, were applied for twelve weeks. Along with these treatments, a complete fertilizer with a 20-20-20 analysis was applied as a fifth treatment at a rate of 200 parts per million N, the standard rate for most greenhouse crop fertilization. The fertilizer solutions were applied by hand to each pot with sufficient water to completely wet the root ball.

Apparently, the test plants did not receive sufficient lighting prior to pinching and the start of the reduced photo-period schedule for flowering. Some premature crown buds formed which detracted from the shape and growth pattern of the plants. Some pesticide spray injury was also incurred, but it was fairly uniform and was determined

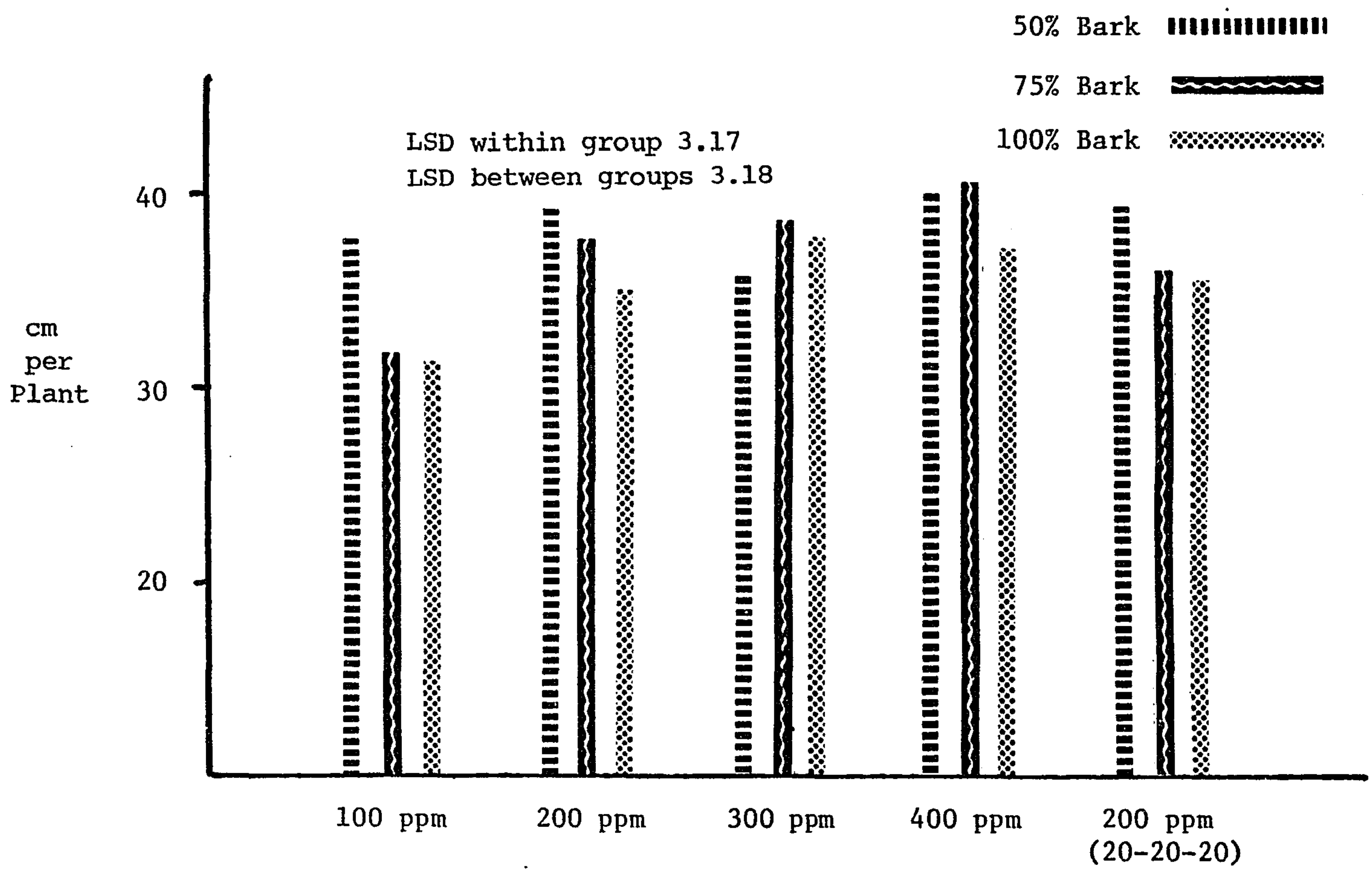

Figure 8. The means for combination of levels of mixes and fertilizers for plant height expressed in centimeters for Experiment 4.

not to influence aspects of specific measurements in the experiment.

The analysis of variance indicated that there was a significant interaction effect between mixes and fertilizers noted for plant height and fresh weight, but there was no significant interaction effect for foliar analysis results for N.

For the analysis of variance, Figure 17a (plant height), 18a (fresh weight), and 19a (foliar N content) follow. Tables 17b and 18b present interaction means for plant height and for fresh weight, respectively. The means for percent foliar N for mixes and fertilizers are in Table 19b.

At N-fertilization level of 100 parts per million from NH_4NO_3, plant height was significantly greater in the 50 percent hardwood bark mix than the height of plants grown in 75 percent and 100 percent bark and greater than the 100 percent bark medium at the 200 parts per million rate (Figure 8). However, at the higher rates of 300 and 400 parts per million fertilizer, there were no significant differences between plant heights in the three mixes. At 200 parts per million, the 20-20-20 fertilizer produced significantly shorter plants in the 100 percent bark medium. The interaction data clearly show that progressively reduced N is needed as the percent bark is reduced.

In general, a similar response was observed on plant fresh weight. At fertilization levels of 100 and 200 parts per million from ammonium nitrate, fresh weight was significantly greater in the 50 percent bark mix than those recorded in the 100 percent hardwood mix. However, at 300 and 400 parts per million, fresh weight was greater in the 100 percent hardwood bark (Figure 9). This pattern was similar to the observations for plant height and could be accounted for if the 300 parts per million weekly rate was supplying the N needs of the mixes containing more of the bark component, which, in turn, was able to release an increased amount of other nutrients for use by the plants. The 200 parts per million N from 20-20-20 was apparently not enough to supply the N needs of the 100 percent bark medium because these plants were significantly lighter in weight than the others grown in 50 percent and 75 percent bark.

Levels of foliar content of N were significantly higher in plants produced in 50 percent bark than in the 100 percent pure bark pots. There were no significant differences between 75 percent and 100 percent bark mixes (Figure 10).

Figure 11 shows the main effect for fertilizers upon foliar N. While a slight trend is evident, there are no significant differences among the various treatments. Only the 400 parts per million application rate provided an N concentration in the leaves greater than the critical level of 2.4 parts per million. However, even the level found there was considerably less than the optimum N range for potted chrysanthemum.

The interaction between N and other nutrients, such as P and K, were not explored in this experiment. Only the 20-20-20 supplied all the major elements plus some trace elements. However, the plants grown with this material did not appear to be visibly better or worse than any other plants in the trial.

Table 17a. ANALYSIS OF VARIANCE FOR PLANT HEIGHT OF PLANTS IN EXPERIMENT 4

Source of Variation	DF	Mean Square
Reps	4	10.0
Mixes	2	46.1
Error A	8	4.9
Fertilizer	4	60.3
Interaction	8	19.3
Error B	48	6.2

Table 17b. THE MEANS OF PLANT HEIGHT EXPRESSED IN CENTIMETERS FOR LEVELS OF MIXES AND FERTILIZERS (NH_4NO_3) and 20-20-20

	Fertilizer Treatments ppm N				
Growing Medium	100	200	300	400	200*
50% Hardwood Bark and Vermiculite	37.6	39.1	35.8	39.7	39.3
75% Hardwood Bark and Vermiculite	31.8	37.5	38.6	40.5	36.0
100% Hardwood Bark	31.5	35.1	38.1	37.1	36.0

$LSD_{.05}$ (between or within groups) = 3.2

*20-20-20

Table 18a. ANALYSIS OF VARIANCE FOR FRESH WEIGHT OF PLANTS IN EXPERIMENT 4

Source of Variation	DF	Mean Square
Reps	4	67.7
Mixes	2	91.8
Error A	8	52.3
Fertilizer	4	276.5
Interaction	8	196.7
Error B	48	33.4

Table 18b. THE MEANS OF FRESH WEIGHT EXPRESSED IN GRAMS FOR LEVELS OF MIXES AND FERTILIZER

	Fertilizer Treatment ppm N				
Growing Medium	100	200	300	400	200*
50% Hardwood Bark and Vermiculite	28.4	33.4	22.8	27.0	28.5
75% Hardwood Bark and Vermiculite	22.1	30.7	30.7	36.5	35.5
100% Hardwood Bark	18.5	22.7	33.1	38.2	24.8

The LSD for comparisons of means within a group is 7.4.
The LSD for comparisons of means between groups is 8.1.
All LSD's at .05 level.

*20-20-20

Table 19a. ANALYSIS OF VARIANCE FOR PERCENT NITROGEN CONTAINED IN THE FOLIAGE OF PLANTS GROWN IN EXPERIMENT 4

Source of Variation	DF	Mean Square
Reps	2	.01
Mixes	2	.30
Error A	4	.04
Fertilizer	4	1.30
Interaction	8	.07
Error B	24	.03

Table 19b. THE MAIN EFFECT MEANS FOR MIXES AND PERTILIZERS FOR PERCENT NITROGEN CONTAINED IN THE FOLIAGE OF PLANTS IN EXPERIMENT 4

Mixes	% N
50% Hardwood Bark and Vermiculite	2.1
75% Hardwood Bark and Vermiculite	1.96
100% Hardwood Bark	1.87
LSD_{05}	.19
Fertilizer Treatments	
100 PPM from NH_4NO_3	1.56
200 PPM from NH_4NO_3	1.98
300 PPM from NH_4NO_3	2.24
400 PPM from NH_4NO_3	2.48
200 PPM from 20-20-20	1.70
$LSD_{.05}$	.17

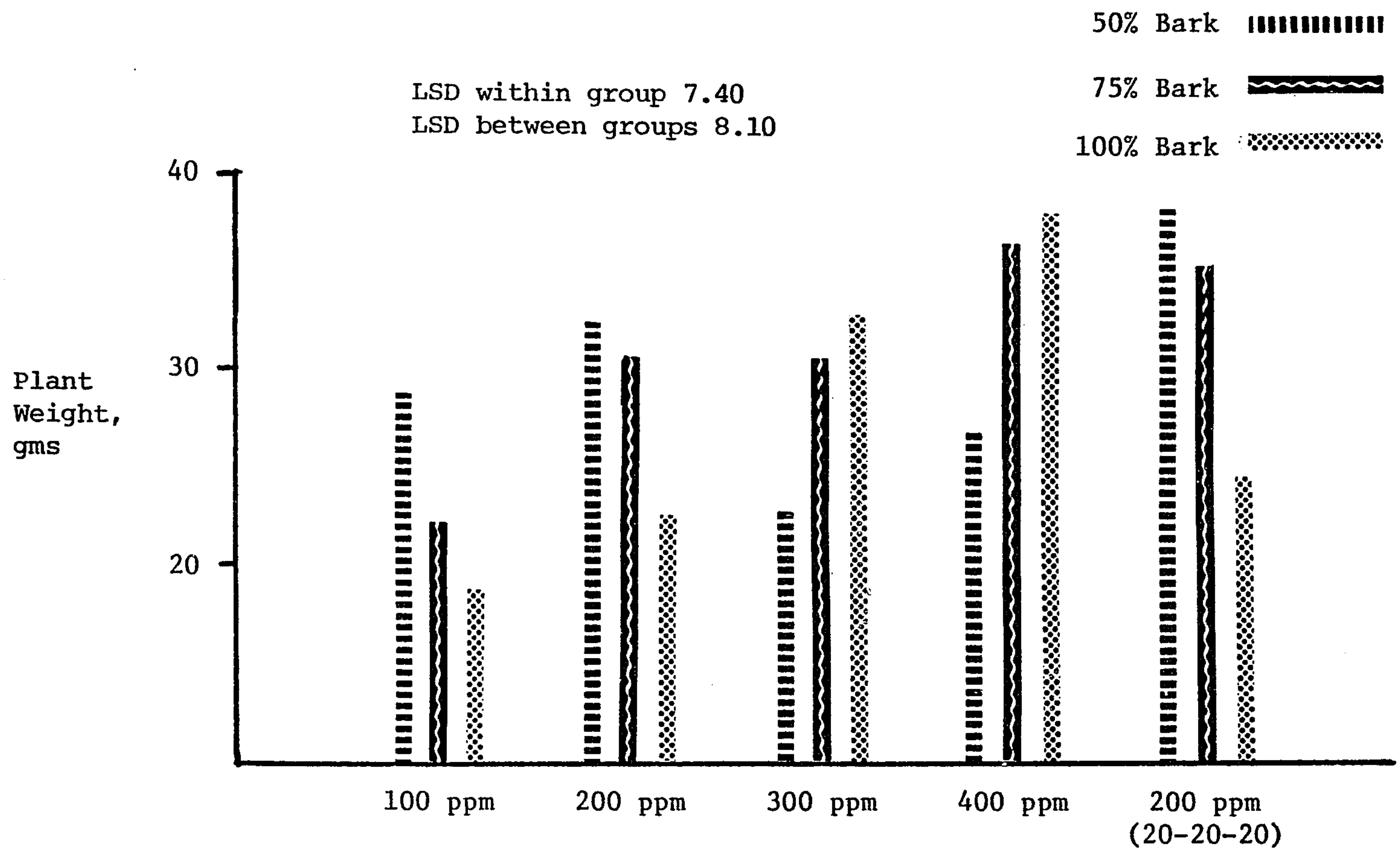

Figure 9. The means for combination of levels of mixes and fertilizers for fresh weight expressed in grams for plants in Experiment 4.

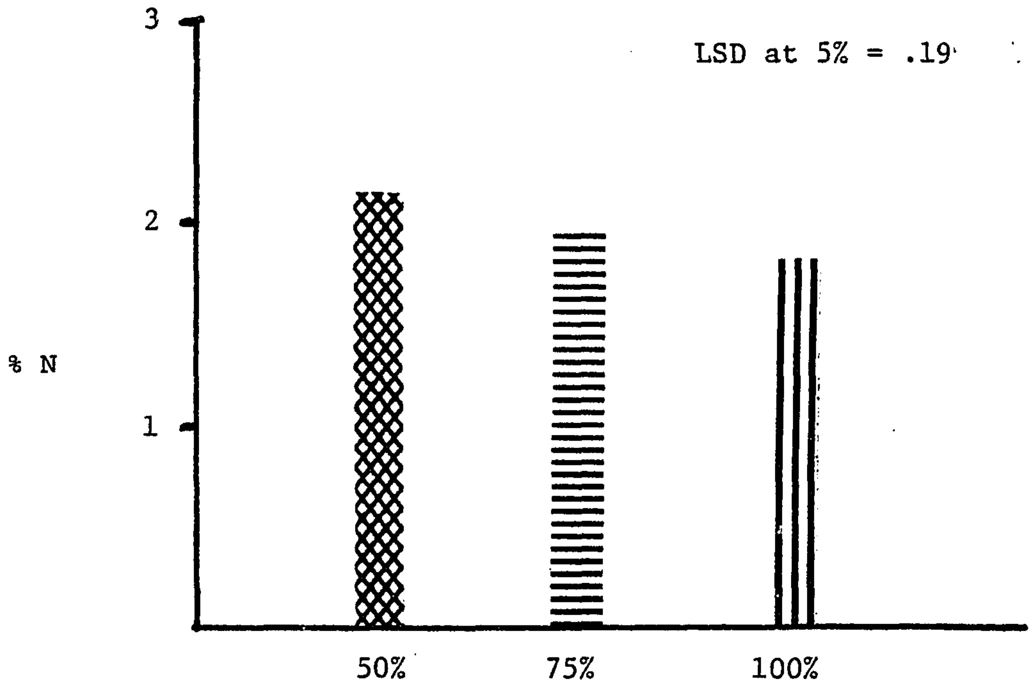

Figure 10. The main effect means for mixes expressed in terms of percent nitrogen in the foliage of plants in Experiment 4.

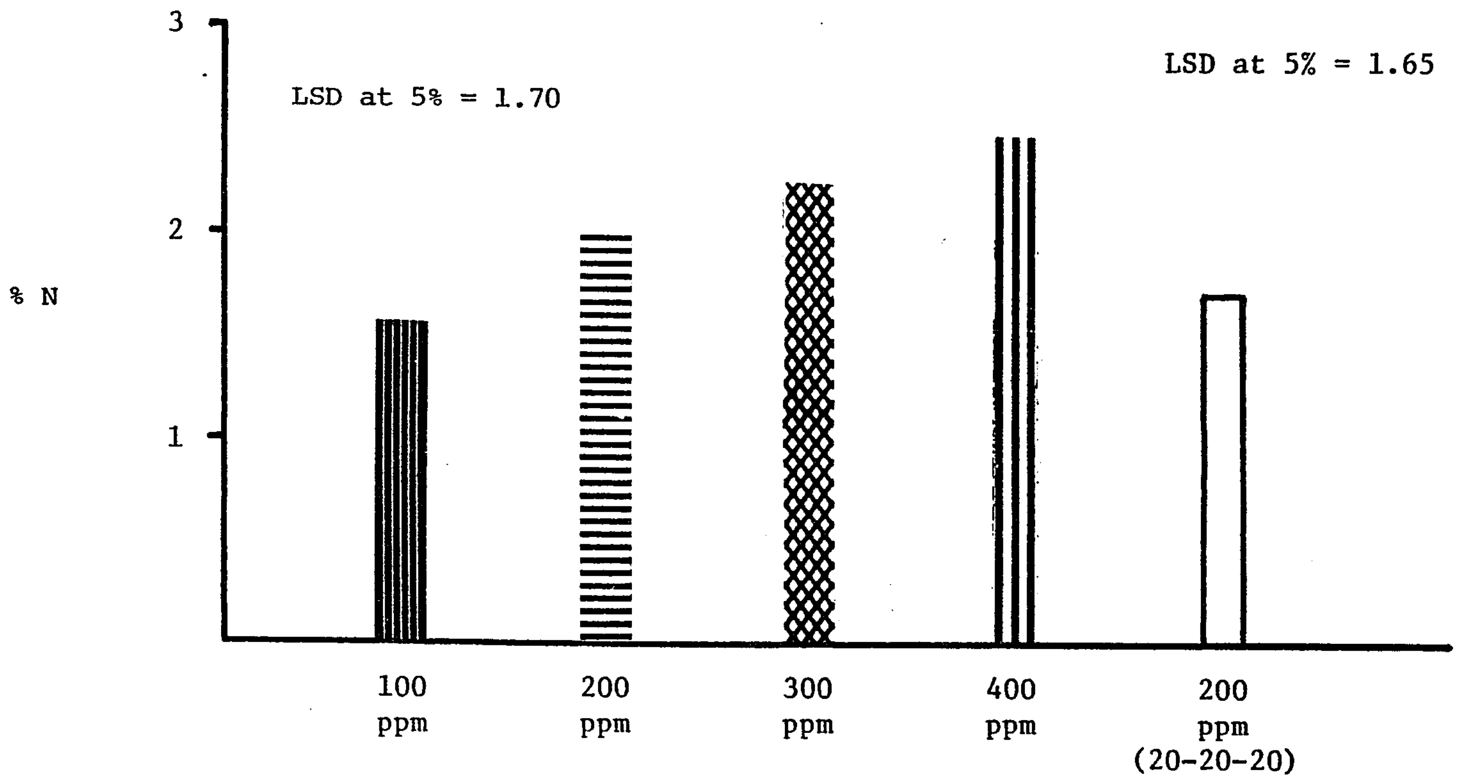

Figure 11. The main effect means for fertilizers expressed in terms of percent nitrogen in the foliage of plants in Experiment 4.

CONCLUSIONS

The potential for economically feasible uses of native hardwood and softwood bark residues does exist in New England. Blends of bark can be used effectively as the organic amendment in soilless growing media for potted greenhouse flowering plants. Variations in tree species, debarking techniques, and processing or handling methods will have an impact on the physical and chemical properties of any bark material used.

Raw bark screened to pass through a 1.9-cm screen can be utilized as a growing medium, but best results are obtained when bark constitutes between 50 percent and 75 percent of the total mixture by volume. The percentage of coarse particles in both fresh hardwood and softwood bark creates greater aeration and drainage capabilities than comparative peat or soil mixtures in container culture. Difficulty in wetting the bark initially and maintaining sufficient moisture levels between irrigations can cause some reduction of early growth of young plants in bark mixes. However, once established, the roots appear to utilize the entire volume of the medium because of the larger pore spaces. Vermiculite was the best inorganic component to be combined with either softwood or hardwood barks. It provided additional K and Mg and supplied some smaller particles to enhance moisture retention and cation exchange capacity.

N is the limiting nutrient element encountered when using fresh bark as a growing medium component. Osmocote 14-14-14 and 18-9-9 proved to be significantly better than Magamp in producing taller, heavier, and better quality plants in the hardwood bark mixtures. There was no significant difference, however, between the Osmocote formulation and Magamp with softwood blends. This lack of difference was attributed to the slightly slower decomposition rate of the pine bark, thus less competition for soil N. Osmocote also has about 50 percent of its N as NO_3, a form readily available to plants. The N in Magamp is all from NH_4 sources. Increased rates of N consistently enhanced plant height and weight in all experiments.

Soluble fertilizers can be used to supply some or all of the plant's nutritional needs when grown in bark mixes. However, with fresh bark blends, it appears that at least 400 parts per million of N are required each week, preferably in the NO_3 form. The upper limits of N fertilization were not established.

Large increases of pH during the growth period were not encountered. Nevertheless, there does not appear to be a need to add limestone because of the high calcium content of bark.

No evidence of plant pathogens, weeds, or any insect problem was observed in the root zones of plants grown in mixtures of unsterilized bark. There was no indication of any stunting or growth reduction that could be attributed to toxic substances in the fresh bark utilized.

When properly watered and fertilized, mixtures of up to 75 percent of bark can be used effectively as a component of soilless growing media for florist greenhouse container production of quality plants. Further studies on composting bark to obtain a more manageable C/N ratio and better particle size range distribution might be suggested.

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